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The United States Air Force High School Apprenticeship Program's (USAF- HSAP) purpose is to place outstanding high school students whose interests are in the areas of mathematics, engineering, and science to work in a laboratory environment. The students selected to participate in the program work in an Air Force Laboratory for a duration of 8 weeks during their summer vacation.

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SUMMER RESEARCH PROGRAM -- 1994

HIGH SCHOOL APPRENTICESHIP PROGRAM FINAL REPORTS

VOLUME 16

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PREFACE

Reports in this volume are numbered consecutively beginning with number 1. Each report is paginated with the report number followed by consecutive page numbers, e.g., 1-1, 1-2, 1-3; 2-1, 2-2, 2-3.

This document is one of a set of 16 volumes describing the 1994 AFOSR Summer Research Program. The following volumes comprise the set:

VOLUME	TITLE
1	Program Management Report
	Summer Faculty Research Program (SFRP) Reports
2A & 2B	Armstrong Laboratory
3A & 3B	Phillips Laboratory
4	Rome Laboratory
5A & 5B	Wright Laboratory
6	Arnold Engineering Development Center, Frank J. Seiler Research Laboratory, and Wilford Hall Medical Center
	Graduate Student Research Program (GSRP) Reports
7	Armstrong Laboratory
8	Phillips Laboratory
9	Rome Laboratory
10	Wright Laboratory
11	Arnold Engineering Development Center, Frank J. Seiler Research Laboratory, and Wilford Hall Medical Center
	High School Apprenticeship Program (HSAP) Reports
12A & 12B	Armstrong Laboratory
13	Phillips Laboratory
14	Rome Laboratory
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1. INTRODUCTION

The Summer Research Program (SRP), sponsored by the Air Force Office of Scientific Research (AFOSR), offers paid opportunities for university faculty, graduate students, and high school students to conduct research in U.S. Air Force research laboratories nationwide during the summer.

Introduced by AFOSR in 1978, this innovative program is based on the concept of teaming academic researchers with Air Force scientists in the same disciplines using laboratory facilities and equipment not often available at associates' institutions.

AFOSR also offers its research associates an opportunity, under the Summer Research Extension Program (SREP), to continue their AFOSR-sponsored research at their home institutions through the award of research grants. In 1994 the maximum amount of each grant was increased from $20,000 to $25,000, and the number of AFOSR-sponsored grants decreased from 75 to 60. A separate annual report is compiled on the SREP.

The Summer Faculty Research Program (SFRP) is open annually to approximately 150 faculty members with at least two years of teaching and/or research experience in accredited U.S. colleges, universities, or technical institutions. SFRP associates must be either U.S. citizens or permanent residents.

The Graduate Student Research Program (GSRP) is open annually to approximately 100 graduate students holding a bachelor's or a master's degree; GSRP associates must be U.S. citizens enrolled full time at an accredited institution.

The High School Apprentice Program (HSAP) annually selects about 125 high school students located within a twenty mile commuting distance of participating Air Force laboratories.

The numbers of projected summer research participants in each of the three categories are usually increased through direct sponsorship by participating laboratories.

AFOSR's SRP has well served its objectives of building critical links between Air Force research laboratories and the academic community, opening avenues of communications and forging new research relationships between Air Force and academic technical experts in areas of national interest; and strengthening the nation's efforts to sustain careers in science and engineering. The success of the SRP can be gauged from its growth from inception (see Table 1) and from the favorable responses the 1994 participants expressed in end-of-tour SRP evaluations (Appendix B).

AFOSR contracts for administration of the SRP by civilian contractors. The contract was first awarded to Research & Development Laboratories (RDL) in September 1990. After completion of the 1990 contract, RDL won the recompetition for the basic year and four 1-year options.

2. PARTICIPATION IN THE SUMMER RESEARCH PROGRAM

The SRP began with faculty associates in 1979; graduate students were added in 1982 and high school students in 1986. The following table shows the number of associates in the program each year.

Table 1: SRP Participation, by Year

YEAR	Number of Participants			TOTAL
	SFRP	GSRP	HSAP	
1979	70			70
1980	87			87
1981	87			87
1982	91	17		108
1983	101	53		154
1984	152	84		236
1985	154	92		246
1986	158	100	42	300
1987	159	101	73	333
1988	153	107	101	361
1989	168	102	103	373
1990	165	121	132	418
1991	170	142	132	444
1992	185	121	159	464
1993	187	117	136	440
1994	192	117	133	442

Beginning in 1993, due to budget cuts, some of the laboratories weren't able to afford to fund as many associates as in previous years; in one case a laboratory did not fund <u>any</u> additional associates. However, the table shows that, overall, the number of participating associates increased this year because two laboratories funded more associates than they had in previous years.

3. RECRUITING AND SELECTION

The SRP is conducted on a nationally advertised and competitive-selection basis. The advertising for faculty and graduate students consisted primarily of the mailing of 8,000 44-page SRP brochures to chairpersons of departments relevant to AFOSR research and to administrators of grants in accredited universities, colleges, and technical institutions. Historically Black Colleges and Universities (HBCUs) and Minority Institutions (MIs) were included. Brochures also went to all participating USAF laboratories, the previous year's participants, and numerous (over 600 annually) individual requesters.

Due to a delay in awarding the new contract, RDL was not able to place advertisements in any of the following publications in which the SRP is normally advertised: *Black Issues in Higher Education, Chemical & Engineering News, IEEE Spectrum* and *Physics Today*.

High school applicants can participate only in laboratories located no more than 20 miles from their residence. Tailored brochures on the HSAP were sent to the head counselors of 180 high schools in the vicinity of participating laboratories, with instructions for publicizing the program in their schools. High school students selected to serve at Wright Laboratory's Armament Directorate (Eglin Air Force Base, Florida) serve eleven weeks as opposed to the eight weeks normally worked by high school students at all other participating laboratories.

Each SFRP or GSRP applicant is given a first, second, and third choice of laboratory. High school students who have more than one laboratory or directorate near their homes are also given first, second, and third choices.

Laboratories make their selections and prioritize their nominees. AFOSR then determines the number to be funded at each laboratory and approves laboratories' selections.

Subsequently, laboratories use their own funds to sponsor additional candidates. Some selectees do not accept the appointment, so alternate candidates are chosen. This multi-step selection procedure results in some candidates being notified of their acceptance after scheduled deadlines. The total applicants and participants for 1994 are shown in this table.

Table 2: 1994 Applicants and Participants

PARTICIPANT CATEGORY	TOTAL APPLICANTS	SELECTEES	DECLINING SELECTEES
SFRP (HBCU/MI)	600 (90)	192 (16)	30 (7)
GSRP (HBCU/MI)	322 (11)	117 (6)	11 (0)
HSAP	562	133	14
TOTAL	1484	442	55

4. SITE VISITS

During June and July of 1994, representatives of both AFOSR/NI and RDL visited each participating laboratory to provide briefings, answer questions, and resolve problems for both laboratory personnel and participants. The objective was to ensure that the SRP would be as constructive as possible for all participants. Both SRP participants and RDL representatives found these visits beneficial. At many of the laboratories, this was the only opportunity for all participants to meet at one time to share their experiences and exchange ideas.

5. HISTORICALLY BLACK COLLEGES AND UNIVERSITIES AND MINORITY INSTITUTIONS (HBCU/MIs)

In previous years, an RDL program representative visited from seven to ten different HBCU/MIs to promote interest in the SRP among the faculty and graduate students. Due to the late contract award date (January 1994) no time was available to visit HBCU/MIs this past year.

In addition to RDL's special recruiting efforts, AFOSR attempts each year to obtain additional funding or use leftover funding from cancellations the past year to fund HBCU/MI associates. This year, seven HBCU/MI SFRPs declined after they were selected. The following table records HBCU/MI participation in this program.

Table 3: SRP HBCU/MI Participation, by Year

YEAR	SFRP		GSRP	
	Applicants	Participants	Applicants	Participants
1985	76	23	15	11
1986	70	18	20	10
1987	82	32	32	10
1988	53	17	23	14
1989	39	15	13	4
1990	43	14	17	3
1991	42	13	8	5
1992	70	13	9	5
1993	60	13	6	2
1994	90	16	11	6

6. SRP FUNDING SOURCES

Funding sources for the 1994 SRP were the AFOSR-provided slots for the basic contract and laboratory funds. Funding sources by category for the 1994 SRP selected participants are shown here.

Table 4: 1994 SRP Associate Funding

FUNDING CATEGORY	SFRP	GSRP	HSAP
AFOSR Basic Allocation Funds	150	98*1	121*2
USAF Laboratory Funds	37	19	12
HBCU/MI By AFOSR (Using Procured Addn'l Funds)	5	0	0
TOTAL	192	117	133

*1 - 100 were selected, but two canceled too late to be replaced.
*2 - 125 were selected, but four canceled too late to be replaced.

7. COMPENSATION FOR PARTICIPANTS

Compensation for SRP participants, per five-day work week, is shown in this table.

Table 5: 1994 SRP Associate Compensation

PARTICIPANT CATEGORY	1991	1992	1993	1994
Faculty Members	$690	$718	$740	$740
Graduate Student (Master's Degree)	$425	$442	$455	$455
Graduate Student (Bachelor's Degree)	$365	$380	$391	$391
High School Student (First Year)	$200	$200	$200	$200
High School Student (Subsequent Years)	$240	$240	$240	$240

APPENDIX A – PROGRAM STATISTICAL SUMMARY

A. Colleges/Universities Represented

Selected SFRP and GSRP associates represent 158 different colleges, universities, and institutions.

B. States Represented

SFRP -Applicants came from 46 states plus Washington D.C. and Puerto Rico. Selectees represent 40 states.

GSRP - Applicants came from 46 states and Puerto Rico. Selectees represent 34 states.

HSAP - Applicants came from fifteen states. Selectees represent ten states.

C. Academic Disciplines Represented

The academic disciplines of the combined 192 SFRP associates are as follows:

Electrical Engineering	22.4%
Mechanical Engineering	14.0%
Physics: General, Nuclear & Plasma	12.2%
Chemistry & Chemical Engineering	11.2%
Mathematics & Statistics	8.1%
Psychology	7.0%
Computer Science	6.4%
Aerospace & Aeronautical Engineering	4.8%
Engineering Science	2.7%
Biology & Inorganic Chemistry	2.2%
Physics: Electro-Optics & Photonics	2.2%
Communication	1.6%
Industrial & Civil Engineering	1.6%
Physiology	1.1%
Polymer Science	1.1%
Education	0.5%
Pharmaceutics	0.5%
Veterinary Medicine	0.5%
TOTAL	100%

Table A-1. Total Participants

Number of Participants	
SFRP	192
GSRP	117
HSAP	133
TOTAL	442

Table A-2. Degrees Represented

Degrees Represented			
	SFRP	GSRP	TOTAL
Doctoral	189	0	189
Master's	3	47	50
Bachelor's	0	70	70
TOTAL	192	117	309

Table A-3. SFRP Academic Titles

Academic Titles	
Assistant Professor	74
Associate Professor	63
Professor	44
Instructor	5
Chairman	1
Visiting Professor	1
Visiting Assoc. Prof.	1
Research Associate	3
TOTAL	192

Table A-4. Source of Learning About SRP

SOURCE	SFRP		GSRP	
	Applicants	Selectees	Applicants	Selectees
Applied/participated in prior years	26%	37%	10%	13%
Colleague familiar with SRP	19%	17%	12%	12%
Brochure mailed to institution	32%	18%	19%	12%
Contact with Air Force laboratory	15%	24%	9%	12%
Faculty Advisor (GSRPs Only)	--	--	39%	43%
Other source	8%	4%	11%	8%
TOTAL	100%	100%	100%	100%

Table A-5. Ethnic Background of Applicants and Selectees

	SFRP		GSRP		HSAP	
	Applicants	Selectees	Applicants	Selectees	Applicants	Selectees
American Indian or Native Alaskan	0.2%	0%	1%	0%	0.4%	0%
Asian/Pacific Islander	30%	20%	6%	8%	7%	10%
Black	4%	1.5%	3%	3%	7%	2%
Hispanic	3%	1.9%	4%	4.5%	11%	8%
Caucasian	51%	63%	77%	77%	70%	75%
Preferred not to answer	12%	14%	9%	7%	4%	5%
TOTAL	100%	100%	100%	100%	99%	100%

Table A-6. Percentages of Selectees receiving their 1st, 2nd, or 3rd Choices of Directorate

	1st Choice	2nd Choice	3rd Choice	Other Than Their Choice
SFRP	70%	7%	3%	20%
GSRP	76%	2%	2%	20%

APPENDIX B – SRP EVALUATION RESPONSES

1. OVERVIEW

Evaluations were completed and returned to RDL by four groups at the completion of the SRP. The number of respondents in each group is shown below.

Table B-1. Total SRP Evaluations Received

Evaluation Group	Responses
SFRP & GSRPs	275
HSAPs	116
USAF Laboratory Focal Points	109
USAF Laboratory HSAP Mentors	54

All groups indicate near-unanimous enthusiasm for the SRP experience.

Typical comments from 1994 SRP associates are:

> "[The SRP was an] excellent opportunity to work in state-of-the-art facility with top-notch people."

> "[The SRP experience] enabled exposure to interesting scientific application problems; enhancement of knowledge and insight into 'real-world' problems."

> "[The SRP] was a great opportunity for resourceful and independent faculty [members] from small colleges to obtain research credentials."

> "The laboratory personnel I worked with are tremendous, both personally and scientifically. I cannot emphasize how wonderful they are."

> "The one-on-one relationship with my mentor and the hands on research experience improved [my] understanding of physics in addition to improving my library research skills. Very valuable for [both] college and career!"

Typical comments from laboratory focal points and mentors are:

> "This program [AFOSR - SFRP] has been a 'God Send' for us. Ties established with summer faculty have proven invaluable."
>
> "Program was excellent from our perspective. So much was accomplished that new options became viable "
>
> "This program managed to get around most of the red tape and 'BS' associated with most Air Force programs. Good Job!"
>
> "Great program for high school students to be introduced to the research environment. Highly educational for others [at laboratory]."
>
> "This is an excellent program to introduce students to technology and give them a feel for [science/engineering] career fields. I view any return benefit to the government to be 'icing on the cake' and have usually benefitted."

The summarized recommendations for program improvement from both associates and laboratory personnel are listed below (Note: basically the same as in previous years.)

A. Better preparation on the labs' part prior to associates' arrival (i.e., office space, computer assets, clearly defined scope of work).

B. Laboratory sponsor seminar presentations of work conducted by associates, and/or organized social functions for associates to collectively meet and share SRP experiences.

C. Laboratory focal points collectively suggest more AFOSR allocated associate positions, so that more people may share in the experience.

D. Associates collectively suggest higher stipends for SRP associates.

E. Both HSAP Air Force laboratory mentors and associates would like the summer tour extended from the current 8 weeks to either 10 or 11 weeks; the groups state it takes 4-6 weeks just to get high school students up-to-speed on what's going on at laboratory. (Note: this same arguement was used to raise the faculty and graduate student participation time a few years ago.)

2. 1994 USAF LABORATORY FOCAL POINT (LFP) EVALUATION RESPONSES

The summarized results listed below are from the 109 LFP evaluations received.

1. LFP evaluations received and associate preferences:

Table B-2. Air Force LFP Evaluation Responses (By Type)

		How Many Associates Would You Prefer To Get ? (% Response)											
		SFRP				GSRP (w/Univ Professor)				GSRP (w/o Univ Professor)			
Lab	Evals Recv'd	0	1	2	3+	0	1	2	3+	0	1	2	3+
AEDC	10	30	50	0	20	50	40	0	10	40	60	0	0
AL	44	34	50	6	9	54	34	12	0	56	31	12	0
FJSRL	3	33	33	33	0	67	33	0	0	33	67	0	0
PL	14	28	43	28	0	57	21	21	0	71	28	0	0
RL	3	33	67	0	0	67	0	33	0	100	0	0	0
WHMC	1	0	0	100	0	0	100	0	0	0	100	0	0
WL	46	15	61	24	0	56	30	13	0	76	17	6	0
Total	121	25%	43%	27%	4%	50%	37%	11%	1%	54%	43%	3%	0%

LFP Evaluation Summary. The summarized repsonses, by laboratory, are listed on the following page. LFPs were asked to rate the following questions on a scale from 1 (below average) to 5 (above average).

2. LFPs involved in SRP associate application evaluation process:
   a. Time available for evaluation of applications:
   b. Adequacy of applications for selection process:
3. Value of orientation trips:
4. Length of research tour:
5 a. Benefits of associate's work to laboratory:
   b. Benefits of associate's work to Air Force:
6. a. Enhancement of research qualifications for LFP and staff:
   b. Enhancement of research qualifications for SFRP associate:
   c. Enhancement of research qualifications for GSRP associate:
7. a. Enhancement of knowledge for LFP and staff:
   b. Enhancement of knowledge for SFRP associate:
   c. Enhancement of knowledge for GSRP associate:
8. Value of Air Force and university links:
9. Potential for future collaboration:
10. a. Your working relationship with SFRP:
    b. Your working relationship with GSRP:
11. Expenditure of your time worthwhile:

(Continued on next page)

12. Quality of program literature for associate:
13. a. Quality of RDL's communications with you:
    b. Quality of RDL's communications with associates:
14. Overall assessment of SRP:

Laboratory Focal Point Reponses to above questions

	AEDC	*AL*	*FJSRL*	*PL*	*RL*	*WHMC*	*WL*
# Evals Recv'd	10	32	3	14	3	1	46
Question #							
2	90 %	62 %	100 %	64 %	100 %	100 %	83 %
2a	**3.5**	**3.5**	4.7	4.4	4.0	4.0	**3.7**
2b	4.0	3.8	4.0	4.3	4.3	4.0	3.9
3	4.2	3.6	4.3	3.8	4.7	4.0	4.0
4	3.8	3.9	4.0	4.2	4.3	NO ENTRY	4.0
5a	4.1	4.4	4.7	4.9	4.3	3.0	4.6
5b	4.0	4.2	4.7	4.7	4.3	3.0	4.5
6a	**3.6**	4.1	**3.7**	4.5	4.3	**3.0**	4.1
6b	3.6	4.0	4.0	4.4	4.7	3.0	4.2
6c	3.3	4.2	4.0	4.5	4.5	3.0	4.2
7a	3.9	4.3	4.0	4.6	4.0	3.0	4.2
7b	4.1	4.3	4.3	4.6	4.7	3.0	4.3
7c	3.3	4.1	4.5	4.5	4.5	5.0	4.3
8	4.2	4.3	5.0	4.9	4.3	5.0	4.7
9	3.8	4.1	4.7	5.0	4.7	5.0	4.6
10a	4.6	4.5	5.0	4.9	4.7	5.0	4.7
10b	4.3	4.2	5.0	4.3	5.0	5.0	4.5
11	4.1	4.5	4.3	4.9	4.7	4.0	4.4
12	4.1	3.9	4.0	4.4	4.7	3.0	4.1
13a	**3.8**	**2.9**	4.0	4.0	4.7	**3.0**	**3.6**
13b	**3.8**	**2.9**	4.0	4.3	4.7	**3.0**	**3.8**
14	4.5	4.4	5.0	4.9	4.7	4.0	4.5

3. 1994 SFRP & GSRP EVALUATION RESPONSES

The summarized results listed below are from the 275 SFRP/GSRP evaluations received.

Associates were asked to rate the following questions on a scale from
1 (below average) to 5 (above average)

1. The match between the laboratories research and your field:		4.6
2. Your working relationship with your LFP:		4.8
3. Enhancement of your academic qualifications:		4.4
4. Enhancement of your research qualifications:		4.5
5. Lab readiness for you: LFP, task, plan:		4.3
6. Lab readiness for you: equipment, supplies, facilities:		4.1
7. Lab resources:		4.3
8. Lab research and administrative support:		4.5
9. Adequacy of brochure and associate handbook:		4.3
10. RDL communications with you:		4.3
11. Overall payment procedures:		3.8
12. Overall assessment of the SRP:		4.7
13. a. Would you apply again?	Yes:	85%
b. Will you continue this or related research?	Yes:	95%
14. Was length of your tour satisfactory?	Yes:	86%
15. Percentage of associates who engaged in:		
a. Seminar presentation:		52%
b. Technical meetings:		32%
c. Social functions:		03%
d. Other		01%

16. Percentage of associates who experienced difficulties in:

a. Finding housing:	12%
b. Check Cashing:	03%

17. Where did you stay during your SRP tour?

a. At Home:	20%
b. With Friend:	06%
c. On Local Economy:	47%
d. Base Quarters:	10%

THIS SECTION FACULTY ONLY:

18. Were graduate students working with you?	Yes:	23%
19. Would you bring graduate students next year?	Yes:	56%

20. Value of orientation visit:

Essential:	29%
Convenient:	20%
Not Worth Cost:	01%
Not Used:	34%

THIS SECTION GRADUATE STUDENTS ONLY:

21. Who did you work with:

University Professor:	18%
Laboratory Scientist:	54%

4. 1994 USAF LABORATORY HSAP MENTOR EVALUATION RESPONSES

The summarized results listed below are from the 54 mentor evaluations received.

1. Mentor apprentice preferences:

Table B-3. Air Force Mentor Responses

		How Many Apprentices Would You Prefer To Get ?			
		HSAP Apprentices Preferred			
Laboratory	***# Evals Recv'd***	***0***	**1**	**2**	**3+**
AEDC	6	0	100	0	0
AL	17	29	47	6	18
PL	9	22	78	0	0
RL	4	25	75	0	0
WL	18	22	55	17	6
Total	**54**	**20%**	**71%**	**5%**	**5%**

Mentors were asked to rate the following questions on a scale from 1 (below average) to 5 (above average)

2. Mentors involved in SRP apprentice application evaluation process:
   a. Time available for evaluation of applications:
   b. Adequacy of applications for selection process:
3. Laboratory's preparation for apprentice:
4. Mentor's preparation for apprentice:
5. Length of research tour:
6. Benefits of apprentice's work to U.S. Air force:
7. Enhancement of academic qualifications for apprentice:
8. Enhancement of research skills for apprentice:
9. Value of U.S. Air Force/high school links:
10. Mentor's working relationship with apprentice:
11. Expenditure of mentor's time worthwhile:
12. Quality of program literature for apprentice:
13. a. Quality of RDL's communications with mentors:
    b. Quality of RDL's communication with apprentices:
14. Overall assessment of SRP:

	AEDC	*AL*	*PL*	*RL*	*WL*
# Evals Recv'd	**6**	**17**	**9**	**4**	**18**
Question #					
2	100 %	76 %	56 %	75 %	61 %
2a	4.2	4.0	**3.1**	**3.7**	**3.5**
2b	4.0	4.5	4.0	4.0	3.8
3	4.3	**3.8**	**3.9**	**3.8**	**3.8**
4	4.5	**3.7**	**3.4**	4.2	**3.9**
5	**3.5**	4.1	**3.1**	**3.7**	**3.6**
6	4.3	3.9	4.0	4.0	4.2
7	4.0	4.4	4.3	4.2	3.9
8	4.7	4.4	4.4	4.2	4.0
9	4.7	4.2	3.7	4.5	4.0
10	4.7	4.5	4.4	4.5	4.2
11	4.8	4.3	4.0	4.5	4.1
12	4.2	4.1	4.1	4.8	3.4
13a	**3.5**	**3.9**	**3.7**	4.0	**3.1**
13b	4.0	4.1	3.4	4.0	3.5
14	4.3	4.5	3.8	4.5	4.1

5. 1994 HSAP EVALUATION RESPONSES

The summarized results listed below are from the 116 HSAP evaluations received.

HSAP apprentices were asked to rate the following questions on a scale from 1 (below average) to 5 (above average)

1. Match of lab research to you interest:		3.9
2. Apprentices working relationship with their mentor and other lab scientists:		4.6
3. Enhancement of your academic qualifications:		4.4
4. Enhancement of your research qualifications:		4.1
5. Lab readiness for you: mentor, task, work plan		3.7
6. Lab readiness for you: equipment supplies facilities		4.3
7. Lab resources: availability		4.3
8. Lab research and administrative support:		4.4
9. Adequacy of RDL's apprentice handbook and administrative materials:		4.0
10. Responsiveness of RDL's communications:		3.5
11. Overall payment procedures:		3.3
12. Overall assessment of SRP value to you:		4.5
13. Would you apply again next year?	Yes:	88%
14. Was length of SRP tour satisfactory?	Yes:	78%
15. Percentages of apprentices who engaged in:		
a. Seminar presentation:		48%
b. Technical meetings:		23%
c. Social functions:		18%

MODELING ENGINE TEST FACILITY CELLS IN VISSIM

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Final Report for:
High School Apprenticeship Program
Arnold Engineering Development Center

Sponsored by:
Air Force Office of Scientific Research
Bolling Air Force Base, DC

and

Arnold Engineering Development Center

August 1994

MODELING ENGINE TEST FACILITY CELLS IN VISSIM

Ryan B. Bond
Tullahoma High School

Abstract

A math package called VisSim was used to model a ram-inlet turbine engine test cell. The package was evaluated for ease of model construction, modification and use. Necessary model run time was also noted. The evaluation indicated that, for analysis purposes, VisSim is preferable to FORTRAN for many test cell models. VisSim did present problems with solving implicit equations and with expressing some logic statements.

MODELING ENGINE TEST FACILITY CELLS IN VISSIM

Ryan B. Bond

Acknowledgments

The author would like to thank Lynn Sebourn, mentor for this project, and all of the EG3 analysis group at Sverdrup Technology, Inc., AEDC operations. Special thanks to David Milleville, Grady Saunders, and Danny Sells for their assistance and guidance. Thanks also to James Mitchell--AEDC HSAP coordinator, AFOSR, and RDL.

Introduction

This research was conducted at the Arnold Engineering Development Center (AEDC). The mission of AEDC is to provide environmental test, evaluation, and analysis support to systems research and development for governmental agencies. AEDC also provides commercial testing to support critical technologies and to maintain cost-effective usage of AEDC facilities. The Engine Test Facility (ETF) is the facility with the responsibility to support aircraft, missile, and spacecraft propulsion-system research and development. Creating an intermediate development stage for testing engines in environmental cells greatly reduces the cost and risk associated with flight testing, the next phase of aerospace systems development.

Most current ETF work involves turbine engine testing. Turbine engine testing requires an air supply able to simulate a wide range of altitudes, Mach numbers, and other environmental conditions (i.e. corrosion tests, icing tests, etc.). Inlet conditions must remain stable during changes in engine operating conditions. In order to keep inlet conditions stable, a control system must be implemented. This system controls valves which adjust the flow of air from one volume into another, or which adjust the flow of hot and cold

lines into a mixing volume. Parameters of the test cell, such as temperature and pressure, are monitored to determine proper positions for the valves after engine throttle changes.

One element of facility management crucial to the upkeep of facilities is analysis engineering. Analysis is examining problem areas in existing systems and evaluating new or upgraded systems. Math modeling is very beneficial in analysis work. Modeling test cells can help diagnose problems in existing cells or prevent potential problems before the construction or modification of a system.

ETF math models are currently operating in FORTRAN using components of control software and additional simulation components derived from 1-D, isentropic flow equations. FORTRAN presents some hindrances to analysis work: It does not allow on-line alterations, it requires compiling, and it is difficult to interpret and modify. VisSim[1,2] is a software package which eliminates some of the hindrances associated with FORTRAN. VisSim represents the structure of the model visually with operator blocks. These operator blocks can be combined into compound blocks, creating a hierarchical diagram. Large VisSim models are easier to interpret and modify than FORTRAN models. Also, VisSim allows on-line alterations and can run with or without compiling (using the compile option increases the speed of the simulation).

The purpose of this study was to build a math model of a ram-inlet test cell (Figure 1) using VisSim. Also, the ease of working in VisSim was to be evaluated; methods of expressing logic loops were to be examined, and any problems with VisSim were to be documented. In addition, assistance was to be given to engineers modeling other problems in VisSim.

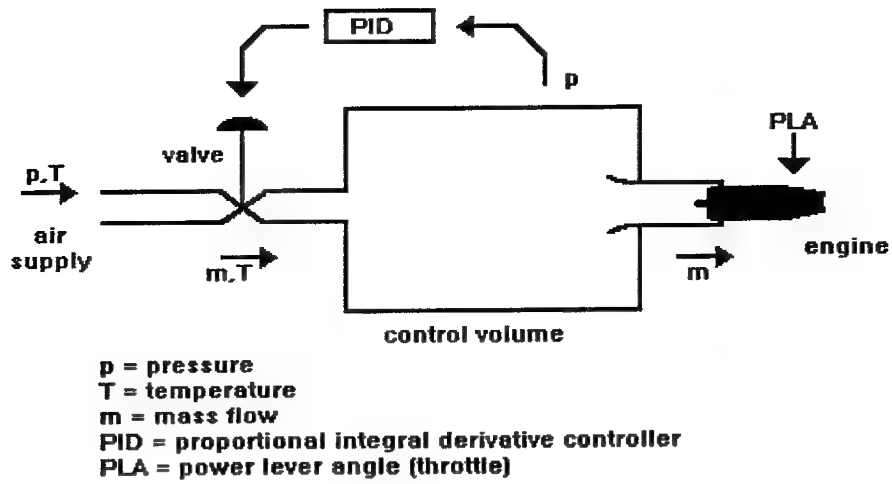

Figure 1

Procedure

Six FORTRAN subroutines from ETF control systems were translated into VisSim: bell, fanspeed, revalve, valve, vapos, and vposa. During the formation of the model, the subroutines vapos and valve were the only two used. Vapos converts a valve position to valve area based on the size and type of the valve. Given upstream and downstream pressures and temperatures, valve computes the flow magnitude and direction through a valve based on valve area. Additional components were added to these two subroutines to build the model: an engine, a control volume, a block to model the valve response, a proportional integral derivative controller, an air supply, and a plot for output. The engine was constructed using 1-D, isentropic flow equations; the control volume was a modified version of an existing VisSim model; the PID and the valve response (a second order lag function) were modified blocks from the VisSim library, and the air supply consisted of user defined values for the pressure and temperature of the source. When the blocks were combined into the model, the sizes of the components and parameters for certain functions were set. To increase the stability of the model, the PID controller was

modified so that it would react to changes in throttle and changes in pressure, rather than just pressure changes. A diagram representing the model in VisSim is shown in Figure 2.

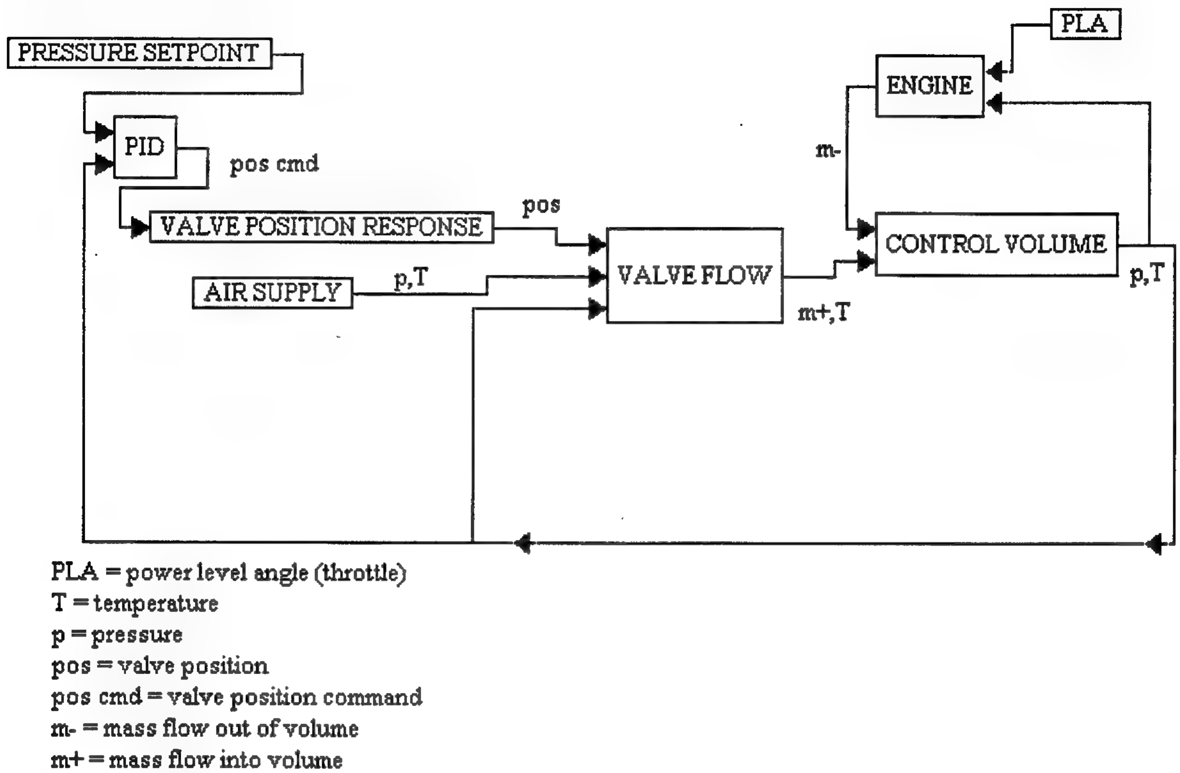

Figure 2

Different ways of expressing logic loops were studied while translating the FORTRAN code into VisSim, and the results were shared with others for implementation in analysis models. Also, four components were constructed in VisSim for use in other models. These included a line (pipe), a line connected to a valve, a line connected to a volume, and a pump. Any potential problems involved with using VisSim for analysis work were reported.

Results

No problems were incurred while translating explicit math operations from FORTRAN into VisSim. However, some problems with logic statements and the implementation of implicit equations were encountered. Many statements

which would be expressed as "if" statements in FORTRAN can be expressed in a single block in VisSim. For example, an "if" loop would be necessary for FORTRAN to evaluate the magnitude of a signal and determine if it is within certain bounds. VisSim requires only one block which compares a signal to a continuous set of real numbers and replaces the signal with the upper or lower limit if the signal is not an element of the set. Many logic loops are not this simple, though. They require extensive use of operator blocks to accomplish what simple FORTRAN statements can accomplish. An "if" loop which determines the execution of one of several operations is simply done in FORTRAN, and the only operation performed is the one intended for relay, but VisSim performs all operations and only uses logic to select between two signals. Logic use in VisSim was improved through the efforts of this project because of the discovery of previously unnoticed logic blocks (i.e. the limit block discussed previously) which were located in poorly labeled menus. This made the logic much simpler than before, but the result of translating a complex logic loop into VisSim still produced a logic diagram difficult to interpret.

In addition to the logic problems, VisSim also presented some other problems. Multiple implicit equations implemented into a model can have unique error tolerance values, but a maximum iteration count must be set universally. Also, many of the shortcut keys do not work and the save option fails to recognize a full disk, locking up the system.

All blocks from the VisSim library performed well after being modified for specific uses in the model. After being modified, the PID controller was able to hold the pressure in the control volume within 1% of the setpoint

throughout the performance envelope of the engine with severe changes in throttle.

Conclusions

This study indicated that VisSim can assist analysis engineers. The model worked very well except for the run time, which was mostly due to the graphics necessary for the plot. Most of the negatives mentioned previously would become problems only in simulations requiring extensive logic and several implicit equations. The failure of some shortcut keys to function properly is insignificant, and when transferring files over the network rather than by floppy disk, chances of encountering a full disk are minimal.

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[1] Beta VisSim version 1.5b
Copyright © 1989-1993, Visual Solutions, Inc.

[2] VisSim
Personal Version 1.2B
Copyright © 1989-1992, Visual Solutions, Inc.

MACH-FLOW ANGULARITY PROBE CALIBRATION

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Final Report for
High School Apprentice Program
Arnold Engineering Development Center

Sponsored by:
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August 1994

MACH-FLOW ANGULARITY PROBE CALIBRATION

Robert B. Cassady
Coffee County Central High School

Abstract

Pratt and Whitney is testing a Scramjet engine for the National AeroSpace Plane. They contracted Calspan Corporation to calibrate the Mach-flow angularity probes for the test. Calspan calibrated the MFA probes for use in a facility that uses air for the flow, which has a gamma (ratio of specific heats) of 1.4; however, Pratt and Whitney is using the MFA probes in an environment other than air that has a gamma of 1.33. My assignment was to find out if there is a significant difference in the data results if theMFA probes calibrated for a gamma of 1.4 are used in a gamma of 1.33 environment.

NOMENCLATURE

M	mach number
γ	ratio of specific heats
θ	shock wave angle measured from upstream flow direction
δ	probe angle
p	pressure
ρ	mass density squared
T	absolute temperature squared
a	speed of sound
A	cross sectonal area of stream tube or channel
V	speed of flow
t	total conditions
*	critical conditions

MACH-FLOW ANGULARITY PROBE CALIBRATION

Robert B. Cassady

Introduction

My mentor prepared me for the project by aking me to create a table that would list the first seven parameters of the National Advisory Committee for Aeronautics 1135 Report (see figure 1 and table 1). This task was accomplished, and in doing so provided me with valuable experience which I used to complete the project. I worked on the project in Excel 4.0 on my computer. All of the equations used in the project and referred to in the paper were taken from the NACA 1135 Report.

Methodology

My project was to determine whether there would be expected to be a significant difference in the data when MFA probes calibrated for air are used in a facility that uses flow other than air. In solving this problem, there were several smaller problems had to be dealt with first. To begin with, I created a table to organize my work and simplify the problem. Then, I studied the equations, (see figure 2), and formulated a plan for solving the problem. That plan was to solve Equation 139b for theta, given that delta equals 15 degrees. Then, using theta in Equation 140, solve the problem using algebra skills. In order to get the results needed, I had to divide Equation 140 by Equation 99, or P2/Pt2, for each gamma in the table (see table 2). The principal problem lay in trying to solve for theta in Equation 139b. The equation was implicit and would be very difficult to solve by hand. I decided to use the computer. In order for the

computer to assist in solving the equation, I wrote a macro that used Solver and Goal Seek to do the iterations needed. After Equation 139b was solved for theta, theta was used in P2/Pt2, and the results are presented in figure 2.

Results

When the results were graphed, it was very clear that only a small difference existed between the solutions of 1.33 and 1.4 as gammas. It was concluded that it will not significantly alter test results if Pratt and Whitney uses probes calibrated for air in a facility that that uses a gas with a gamma of 1.33.

REFERENCES

1. National Advisory Committee for Aeronautics Report 1135

2. Strike, W. T. Jr. Thirty Years of Evolution, Calibration, and Application of Miniature Mach-Flow Angularity Probes in the AEDC Supersonic/ Hypersonic Wind Tunnels. Dec. 1993. Report number AEDC-TR-93-13.

EQUATIONS USED IN TABLE I
(TAKEN FROM NACA 1135)

FIGURE 1

$$\frac{P}{P_t} = \left(1 + \frac{\gamma - 1}{2} M^2\right)^{\frac{-\gamma}{\gamma-1}}$$ (EQ. 44)

$$\frac{\rho}{\rho_t} = \left(1 + \frac{\gamma - 1}{2} M^2\right)^{-\frac{1}{\gamma-1}}$$ (EQ. 45)

$$\frac{T}{T_t} = \left(1 + \frac{\gamma - 1}{2} M^2\right)^{-1}$$ (EQ. 43)

$$\beta = \sqrt{\left| M^2 - 1 \right|}$$

$$\frac{q}{p_t} = \frac{\gamma}{2} M^2 \left(1 + \frac{\gamma - 1}{2} M^2\right)^{-\frac{\gamma}{\gamma-1}}$$ (EQ. 48)

$$\frac{A}{A_*} = 1 \Big/ \left(\left(\frac{\gamma - 1}{2}\right)^{\frac{\gamma+1}{2(\gamma-1)}} M \left(1 + \frac{\gamma - 1}{2} M^2\right)^{-\frac{\gamma+1}{2(\gamma-1)}} \right)$$ (EQ. 80)

$$\frac{V}{a_*} = \sqrt{\left(\frac{\gamma + 1}{2} M^2 \left(1 + \frac{\gamma - 1}{2} M^2\right)^{-1} \right)}$$ (EQ.50)

TABLE I

NACA 1135 TABLE FOR SUBSONIC AND SUPERSONIC FLOW

M	p/pt	ρ/ρτ	T/Tt	ß	q/pt	A/A*	V/a*
0.01	0.99993	0.99995	0.99998	0.99995	7E-05	57.87384	0.010954
0.02	0.99972	0.9998	0.99992	0.9998	0.00028	28.94213	0.021908
0.03	0.99937	0.99955	0.99982	0.99955	0.00063	19.30054	0.03286
0.04	0.998881	0.9992	0.99968	0.9992	0.001119	14.48149	0.043811
0.05	0.998252	0.998751	0.9995	0.998749	0.001747	11.59144	0.054759
0.06	0.997484	0.998202	0.999281	0.998198	0.002514	9.66591	0.065703
0.07	0.996578	0.997554	0.999021	0.997547	0.003418	8.291525	0.076644
0.08	0.995533	0.996807	0.998722	0.996795	0.00446	7.26161	0.08758
0.09	0.994351	0.995961	0.998383	0.995942	0.005638	6.461342	0.09851
0.1	0.993031	0.995017	0.998004	0.994987	0.006951	5.821829	0.109435
2.1	0.109353	0.205803	0.53135	1.846619	0.337573	1.836944	1.676873
2	0.127805	0.230048	0.555556	1.732051	0.357853	1.6875	1.632993
1.9	0.14924	0.256991	0.58072	1.615549	0.377128	1.555257	1.586089
1.8	0.17404	0.286818	0.606796	1.496663	0.394723	1.438982	1.535976
1.7	0.202593	0.319693	0.633714	1.374773	0.409847	1.337606	1.48247
1.6	0.235271	0.35573	0.661376	1.249	0.421606	1.250235	1.425393
1.5	0.272403	0.394984	0.689655	1.118034	0.429035	1.176167	1.364576
1.4	0.314241	0.437423	0.718391	0.979796	0.431138	1.114926	1.298867
1.3	0.360914	0.482903	0.747384	0.830662	0.426961	1.066305	1.231136
1.2	0.412377	0.531142	0.776398	0.663325	0.415676	1.03044	1.158281
1.1	0.468354	0.581696	0.805153	0.458258	0.396696	1.007925	1.081241
12	5.92E-06	0.000206	0.033557	11.95826	0.000698	1276.215	2.40804
12.5	5.25E-06	0.000169	0.031008	12.45994	0.000574	1552.871	2.411214
13	4.02E-06	0.00014	0.028736	12.96148	0.000476	1876.077	2.414039
13.5	3.11E-06	0.000117	0.026702	13.46291	0.000397	2251.531	2.416565
14	2.43E-06	9.76E-05	0.024876	13.96424	0.000333	2685.384	2.418832
14.5	1.91E-06	8.22E-05	0.023229	14.46548	0.000281	3184.254	2.420873
15	1.51E-06	6.97E-05	0.021739	14.96663	0.000239	3756.247	2.422719
15.5	1.21E-06	5.93E-05	0.020387	15.46771	0.000203	4405.971	2.424392
16	9.73E-07	5.08E-05	0.019157	15.96872	0.000174	5144.655	2.425914
16.5	7.88E-07	4.37E-05	0.018034	16.46967	0.00015	5979.667	2.427302
24	5.91E-08	6.87E-06	0.008606	23.97916	2.38E-05	37832.36	2.438927
25	4.45E-08	5.61E-06	0.007937	24.97999	1.95E-05	46305	2.43975
26	3.39E-08	4.62E-06	0.007342	25.98076	1.6E-05	56235.98	2.440481
27	2.61E-08	3.83E-06	0.006812	26.98148	1.33E-05	67806.4	2.441133
28	2.03E-08	3.2E-06	0.006337	27.98214	1.11E-05	81211.82	2.441716
29	1.59E-08	2.69E-06	0.00591	28.98275	9.34E-06	96662.79	2.442241
30	1.25E-08	2.27E-06	0.005525	29.98333	7.8E-06	114386.4	2.442714
31	9.98E-09	1.93E-06	0.005176	30.98387	6.71E-06	134622	2.443142
32	8E-09	1.65E-06	0.004859	31.98437	5.73E-06	157631.3	2.443531
33	6.45E-09	1.41E-06	0.00457	32.98485	4.92E-06	183689.5	2.443886

EQUATIONS USED IN TABLE II
(TAKEN FROM NACA 1135)

FIGURE 2

$$\frac{P_{t_2}}{P_{t_1}} = \left[\frac{(\gamma+1)M_1^2}{(\gamma-1)M_1^2+2}\right]^{\frac{\gamma}{\gamma-1}} \left[\frac{\gamma+1}{2\gamma M_1^2-(\gamma-1)}\right]^{\frac{1}{\gamma-1}} \qquad \text{(EQ. 99)}$$

$$\tan\delta = \frac{M_1^2 \sin 2\theta - 2\cot\theta}{2 + M_1^2(\gamma + \cos 2\theta)} \qquad \text{(EQ.139b)}$$

$$\frac{P_2}{P_{t_1}} = \frac{2\gamma M_1^2 \sin^2\theta - (\gamma-1)}{(\gamma+1)} \left[\frac{2}{(\gamma-1)M_1^2+2}\right]^{\frac{\gamma}{\gamma-1}} \qquad \text{(EQ. 140)}$$

Initial Guess= 1

TABLE II COMPARISON FOR GAMMA = 1.33 AND GAMMA = 1.4

							EQ. 99		EQ. 140	
γ	M	Theta(deg)	THETA	Del(deg)	Del(rad)	tan(Del)	PT2/PT1	EQ. 139b	P2/PT1	P2/PT2
1.33	2	44.643	0.779161	15	0.261799	0.267949	0.706992	0.2679252	0.274049	0.387626
1.33	2.25	39.821	0.695008	15	0.261799	0.267949	0.585032	0.2676786	0.192838	0.329619
1.33	2.5	36.400	0.635299	15	0.261799	0.267949	0.47302	0.2678921	0.136317	0.288185
1.33	2.75	33.795	0.589836	15	0.261799	0.267949	0.376467	0.2679362	0.096679	0.256806
1.33	3	31.711	0.553453	15	0.261799	0.267949	0.296632	0.2673755	0.068804	0.23195
1.33	3.25	30.065	0.524733	15	0.261799	0.267949	0.232405	0.2676993	0.049438	0.212722
1.33	3.5	28.700	0.500917	15	0.261799	0.267949	0.181647	0.2678394	0.03579	0.19703
1.33	3.75	27.554	0.48091	15	0.261799	0.267949	0.141974	0.2679007	0.026132	0.184065
1.33	4	26.580	0.46391	15	0.261799	0.267949	0.11116	0.2679277	0.019256	0.173229
1.33	4.25	25.744	0.449323	15	0.261799	0.267949	0.087296	0.2679396	0.014323	0.164077
1.33	4.5	24.979	0.435974	15	0.261799	0.267949	0.068822	0.2671598	0.010721	0.155773
1.33	4.75	24.363	0.425214	15	0.261799	0.267949	0.054501	0.2674368	0.008134	0.149243
1.33	5	23.818	0.41571	15	0.261799	0.267949	0.043371	0.2676148	0.006226	0.143544
1.33	5.25	23.335	0.40728	15	0.261799	0.267949	0.034691	0.2677299	0.004806	0.138546
1.33	5.5	22.905	0.39977	15	0.261799	0.267949	0.027893	0.2678048	0.003742	0.134142
1.33	5.75	22.520	0.393054	15	0.261799	0.267949	0.022546	0.2678537	0.002936	0.130243
1.33	6	22.175	0.387025	15	0.261799	0.267949	0.018319	0.2678858	0.002322	0.126777
1.4	2	45.341	0.791349	15	0.261799	0.267949	0.720874	0.2679124	0.280459	0.389054
1.4	2.25	40.407	0.70524	15	0.261799	0.267949	0.60553	0.267613	0.20021	0.330636
1.4	2.5	36.941	0.644737	15	0.261799	0.267949	0.499015	0.2678772	0.144387	0.289344
1.4	2.75	34.310	0.598822	15	0.261799	0.267949	0.406226	0.2679327	0.104875	0.258168
1.4	3	32.205	0.562086	15	0.261799	0.267949	0.328344	0.267312	0.076655	0.233459
1.4	3.25	30.553	0.533257	15	0.261799	0.267949	0.264506	0.2676702	0.056727	0.214466
1.4	3.5	29.185	0.509372	15	0.261799	0.267949	0.212948	0.2678261	0.04237	0.198968
1.4	3.75	28.036	0.489327	15	0.261799	0.267949	0.171665	0.2678946	0.031959	0.186168
1.4	4	27.062	0.472313	15	0.261799	0.267949	0.138756	0.2679249	0.024348	0.175474
1.4	4.25	26.226	0.457728	15	0.261799	0.267949	0.112561	0.2679384	0.018735	0.166446
1.4	4.5	25.457	0.444308	15	0.261799	0.267949	0.091698	0.2671049	0.014506	0.158192
1.4	4.75	24.843	0.433598	15	0.261799	0.267949	0.075047	0.2673986	0.01139	0.151777
1.4	5	24.302	0.424142	15	0.261799	0.267949	0.061716	0.2675881	0.009021	0.146175
1.4	5.25	23.821	0.415756	15	0.261799	0.267949	0.051005	0.2677113	0.007205	0.141261
1.4	5.5	23.393	0.40829	15	0.261799	0.267949	0.042361	0.2677917	0.005801	0.136931
1.4	5.75	23.011	0.401617	15	0.261799	0.267949	0.035356	0.2678445	0.004706	0.133097
1.4	6	22.668	0.395629	15	0.261799	0.267949	0.029651	0.2678794	0.003845	0.129688

Workstation Inventory Control Program

Thomas Clouse

Coffee County Central High School
Manchester, TN

Final Report for:
High School Apprentice Program

Sponsored by:
Air Force Office of Scientific Research
Bolling Air Force Base, DC

and

Arnold Engineering Development Center

August 1994

Abstract:

A Database Program was created to inventory hardware and software for new workstation Computers. The program also records problems with the new systems.

Acknowledgements:

I would like to thank my mentor Ron Turner and backup mentor Randy Sloan not only for their help with my program but also for their good jokes.

I would like to thank Margariete Coop for being so kind to me and making really, really good brownies and other treats

I would like to thank James D. Mitchell his contributions to the program and also because he is cool.

General Description of Research:

Six months ago, my mentor and some of his co-workers began working on new workstation computers. My assignment was to create a database program to inventory hardware and software and to record problems occurring with the new workstations. I first familiarized myself with the personal computer and worked through the tutorial for FoxPro 2.5 for Windows. I then built the program using the FoxPro software. During the final days of the program, I streamlined and simplified the program. The project was a success and will soon be put into use.

Workstation Inventory Control Program

Approximately six months ago, my mentor and some of his co-workers began developing programs for new workstation computers. The project has now grown to include over seventy-five workstations and 500 pieces of hardware spread across ten buildings. The workstations utilize six different operating systems, contain twenty types of software, and cost approximately six million dollars. My assignment in the apprenticeship program was to create a database program to inventory all these pieces of equipment and to record problems occurring with the workstations.

To store the necessary workstation data, I chose FoxPro 2.5 for Windows to create a relational database program. The advantage of a relational database program is that less duplication is required; different databases can be joined to each other by relating a common field from each table.I began my project by first familiarizing myself with the personal computer, windows, and FoxPro 2.5 for Windows. I spent the first week of the High School Apprenticeship Program working through the book long tutorial of FoxPro 2.5 for Window. I then spent some time experimenting with building simple programs.

After building a few successful programs with FoxPro, I began building my workstation database project. My first step structure the database tables. I divided the fields to allow for as little duplication as possible and began building the databases. The database included over thirty fields in seven different databases.(See Figure 1) The databases are related by unique five digit number called the CPU number. The CPU number is linked almost directly to the system name with the exception of hardware unassigned to a workstation.

The next step was to create screens for my database tables. Screens allow for a much easier form of input and output than database tables. The FoxPro version for Windows proved to be a big advantage when building screens because the information is displayed in basically the same form that appears on the screen. After creating screens for each of the five databases, I used the FoxApp application generator to build programs for each of the databases.

After generating the screen programs, I opened new queries for each of the tables. Queries gather information from one or more databases and put the information into a new form such as a label, report, graph, or even another table. I used the information gathered in the queries to make reports that displayed database information in print.

After completing the database tables, screens, queries, and reports for all seven databases, I created a menu that included each of the elements as an option. I then generated a menu program that provides for easy access to all of the databases.(see Figure 2 and Figure 3 for the menu options)

I then opened a new project folder and added each of the databases-along with each of its components. The project folder ties all of the elements of a program together to allow a single application to be generated. A project also keeps a record of each of its elements and insures that all files are keep up-to-date. I finally generated an application using the project folder.

Results:

I Created Effective Inventory Control Program That:

- Inventories Workstation Hardware and Software
- Keeps a Record of All Problems with the Workstations
- Provides a Simple Method to Manipulate Almost Thirty Fields in Six Different Databases
- Supplies Ready-Made Reports to Display Information on Paper

Through the High School Apprenticeship Program I Gained:

+ A Better Understanding of the Complexities of Computer Program Development
+ Valuable Experience on the PC and Working With Windows
+ The Ability to Create and Manipulate Databases with FoxPro 2.5 for Windows
+ Greater Understanding of Life In General Due to the Stories of James D. Mitchell
+ Experience Working in an Office Environment

Figure 1: FIELDS LIST

CPU INFORMATION

CPU Number
Air Force Number
Model
Serial Number
E-Net Address
IP Address
Domain Name
Building
Location

INTERNAL DEVICES

CPU Number
Item

SOFTWARE

CPU Number
Product
Version
License Key

SYSTEM NAME

CPU Number
System Name

TROUBLE LOG

CPU Number
Date Reported
Repaired?
Date Repaired
Type
Key Word Field
Problem Description
Solution

MONITOR INFORMATION

CPU Number
Air Force Number
Model
Serial Number
Building
Location

PERIPHERALS

CPU Number
Air Force Number
Model
Serial Number
Type
Building
Location

Figure 2

- Main Menu
  - Workstations
    - Hardware
      - CPU Information
      - Internal Devices
      - Monitor Information
      - Peripherals
    - Software
    - Trouble Log
    - Exit Workstations
  - Reports
    - CPU Information
    - Internal Devices
    - Peripherals
    - Software
    - Trouble Log
    - Monitor Information
    - System
    - Location
  - Window
    - Clear
    - Cycle
    - Command
    - View
  - Help
    - Help Contents
    - Calculator
    - Calendar
    - Filer
    - Puzzle

Figure 3

- Application Chosen
  - File
    - Print Setup
    - Quit
  - Edit
    - Cut
    - Copy
    - Paste
    - Paste Special
    - Clear
    - Insert Object
    - Object
    - Change Link
    - Convert to Static
    - Select All
    - Preferences
  - Application
    - Top
    - Bottom
    - Next
    - Prior
    - Cycle
    - Add Record
    - Copy Record
    - Delete Record
    - Browse
    - Search
    - Filter
    - Order
    - Query
    - Report
  - Utilities
    - Refresh Screen
    - Construct Index
    - Pack
  - Help
    - Help Contents
    - Macros
    - Calculator
    - Calendar
    - Puzzle

THE CONVERSION OF MILLIVOLTS MEASURED FROM THERMOCOUPLES INTO CORRESPONDING DEGREES FAHRENHEIT USING THE TABLE LOOKUP METHOD

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Final Report for:
High School Apprentice Program
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August 1994

THE CONVERSION OF MILLIVOLTS MEASURED FROM THERMOCOUPLES INTO CORRESPONDING DEGREES FAHRENHEIT USING THE TABLE LOOKUP METHOD

Michael L. Fann
Tullahoma High School

Abstract

It was determined that a new program was needed to convert the millivolts measured from thermocouples into corresponding degrees Fahrenheit. This program should incorporate a new method entitled table lookup using a millivolt index into a table of temperature values and linear interpolation between values. The table lookup technique would replace the use of polynomial curve fit equations of the thermocouple tables. The new method would read the thermocouple tables and select the temperature value that corresponds with the measured millivolt value. This method of converting millivolts to temperature should prove to be more accurate. It was desired that this method would meet within the new desired tolerance of +/- 0.05 degree over the temperature range of -30 to +300 degrees Fahrenheit and a tolerance of +/- 0.1 over the rest of the range. A program was developed to incorporate the table lookup method of converting millivolts to corresponding degrees Fahrenheit. This program also enables the user to convert degrees Fahrenheit to millivolts. After completion, the program met the desired tolerance and with this improved accuracy the program could replace the current conversion program.

THE CONVERSION OF MILLIVOLTS MEASURED FROM THERMOCOUPLES INTO CORRESPONDING DEGREES FAHRENHEIT USING THE TABLE LOOKUP METHOD

Michael L. Fann

Introduction

For thermocouple measurements, the common technique for conversion from measured millivolts to temperature is to use polynomial curve fit equations of the thermocouple tables defined by the National Institute of Standards and Technology (NIST) (1). These polynomials are multi-segmented and in some cases are as high as the 5th order. An evaluation was made of the errors obtained when using this method, referred to as the "temperature function." The evaluation was based on the National Institute of Standards and Technology (NIST) Monograph 175. Using the polynomials given in Monograph 175 to generate the millivolt tables (truth), temperature in ten degree increments over the range of each type of thermocouple was input to the polynomials and the millivolt output of the polynomials then input to the "temperature function." The errors found in this evaluation were greater than the +/- 0.1 degree Fahrenheit tolerance that was suggested. However, an even tighter tolerance of +/- 0.05 degree over the range of -30 to +300 degrees Fahrenheit is now recommended(2).

Now, an alternate method of converting millivolts to temperature in thermocouple readings has been introduced. This method trades required machine speed for storage requirements(2). This method, referred to as "table lookup," is expected to meet the new tighter tolerance of +/- 0.05 over the range of -30 to +300 degrees Fahrenheit and within +/- 0.1 over the rest of the table. This new method must be incorporated into a function that is programmed to replace the old "temperature function" so that it may be used in testing.

Discussion of Problem

In order to incorporate this method, a program must be developed to read the various thermocouple tables that have been defined by the National Institute of Standards and Technology (NIST). This program, developed in Fortran, must be able to have millivolts and the type thermocouple inputted and be able to give the corresponding temperature within the desired tolerance. This program must be programmed to replace the "temperature function" with the same variables so that a quick transition from the old "temperature function" to the new method may be achieved easily. The program must also work with reasonable speed and use previously developed algorithms to read and interpolate inside the eight different thermocouple tables.

Methodology

The process of developing a new "temperature function" which uses the lookup table technique to convert measured millivolts from thermocouples to corresponding degrees Fahrenheit started by creating a small program that could operate on its own. This program was required to use previously established algorithms to read from sixteen different thermocouple files. However, to incorporate these algorithms into the function, many adjustments had to be made. The algorithms were modified to choose the corresponding temperature value. Additional modifications were also made to the algorithms so that they would work correctly in both the positive and negative temperature ranges. Additional commands were also required so that the algorithms selected the correct values on the extremes of the ranges of the tables. These modifications and additions created much improved accuracy. The new function outputs temperature values within the tolerances that have been specified. After the function was complete and in working order, it was transformed into a subprogram and loaded onto the VAX-8650 computer system to be tested for use. These tests were carried out and it was found that the new "temperature function" readings were more accurate than the old "temperature function" and were within the desired tolerance. However, the new "temperature function" was considerably slower in computing the temperature values, so further modifications had to be made

before it would be ready for testing. The function was divided into a subroutine and a subprogram. The subroutine was developed to read all the thermocouple tables and to store them in memory as arrays. This subroutine is called once for the entire program and the arrays are kept in memory. The subprogram simply searches the table for the correct temperature value. The addition of this subroutine allows the new "temperature function" to operate much faster since the files are only opened once rather than opening and closing the specified type table for each millivolt value. After these additional improvements were made the new "temperature function" was found to work with comparable speed in addition to giving more accurate temperature values. This completed the work on the construction of the new "temperature function." After completion, the function met all the previously established requirements and was ready to be incorporated in testing.

The source codes for the "new temperature function" and the subroutine which opens and reads the tables are listed on the next five pages.

```
C                   INPUT:
C                          A   = INDEPENDENT VARIABLE
C                       KODE   = THERMOCOUPLE TYPES
C                                1=J,2=T,3=K,4=S,5=R,6=B,7=E,8=N
C
C                   OUTPUT:
C                      TMPRF   = VALUE OF DEPENDENT VARIABLE
C
C         X = ARRAY WHERE TABLE IS STORED
C       LOC = LOCATION OF DEPENDENT MILLIVOLT/TEMPERATURE
C             CORRESPONDING WITH THE INDEPENDENT ARRAY
C       X(1)= NUMBER OF INDEPENDENT VARIABLES
C       X(2)= FIRST INDEPENDENT VARIABLE MILLIVOLTS/TEMPERATURE
C       TMF = VALUE OF DEPENDENT VARIABLE AT A(LOC)
C       TMF1= VALUE OF THE DEPENDENT VARIABLE FOLLOWING A(LOC)
C       TML = LINEARLY INTERPOLATED RESULT FOR THE MEASURED TEMP
C
      FUNCTION XTMP(A,KODE)
      COMMON/XARRAY/X(80000,18)
      IF (KODE.GE.10.AND.KODE.LE.18) GOTO 150
C
C      DETERMINE IF INPUT VALUE IS BELOW RANGE OF MILLIVOLT TABLE
C      IF BELOW RANGE OF TABLE USE FIRST DEPENDENT VALUE
C
       IF ( A .LE. X(2) ) THEN
       TMPRF = X( X(1)+2)
       RETURN
       ENDIF
C
C      DETERMINE IF INPUT VALUE IS ABOVE RANGE OF MILLIVOLT TABLE
C      IF ABOVE RANGE OF TABLE USE LAST DEPENDENT VALUE
C
       IF ( A .GE. X(X(1)+1)) THEN
          TMPRF = X(2*(X(1))+1)
          RETURN
       ENDIF
C
C      ALGORITHM FOR MILLIVOLTS TO TEMPERATURE
C
       LOC=INT((A-X(2))*100.0 +.5)+(X(1)+2)
       TMF=X(LOC)
       TMF1=X(LOC+1)
       F=A*100.0
       K=INT(A*100.0-0.5)
       IF (A .LT. 0.0)THEN
          TMPRF=TMF+(TMF1-TMF)*(A*100.-INT(A*100.- 0.5))
       ELSE
          TMPRF=TMF+(TMF1-TMF)*(A*100.-INT(A*100.+ 0.5))
       ENDIF
       Return
```

```
C
C       DETERMINE IF INPUT VALUE IS BELOW RANGE OF TEMPERATURE
C       TABLE IF BELOW RANGE OF TABLE USE FIRST DEPENDENT VALUE
C
150     CONTINUE
        IF ( A .LE. X(2,KODE) ) THEN
           XTMP = X(( X(1,KODE)+2),KODE)
           RETURN
        ENDIF
C
C       DETERMINE IF INPUT VALUE IS ABOVE RANGE OF TEMPERATURE
C       TABLE IF ABOVE RANGE OF TABLE USE LAST DEPENDENT VALUE
C
        IF ( A .GE. X((X(1,KODE)+1),KODE)) THEN
           XTMP = X((2*(X(1,KODE))+1),KODE)
           RETURN
        ENDIF
C
C       ALGORITHM FOR TEMPERATURE TO MILLIVOLTS
C
        LOC=INT((A-X(2,KODE))*10.0+.5)+(X(1,KODE)+2)
        TMF=X(LOC,KODE)
        TMF1=X(LOC+1,KODE)
        IF (A .LT. 0.0)THEN
           XTMP=TMF+(TMF1-TMF)*(A*100.-INT(A*100.- 0.5))
        ELSE
           XTMP=TMF+(TMF1-TMF)*(A*100.-INT(A*100.+ 0.5))
        ENDIF
        Return
        End
```

```
      SUBROUTINE TMPREAD(KODE)
      Character*26 FILNT(8), FILNM(8)
      CHARACTER*10 FILNX(8),FILNY(8)
      Character*80 HEADER1, HEADER2
      Dimension Y(40000,8), IC(8)
      COMMON /XARRAY/X(80000,18)
C
C     MILLIVOLT TO TEMPERATURE FILENAME TABLES
C
      Data FILNX /'J_MV2T.TXT','T_MV2T.TXT','K_MV2T.TXT',
                  'S_MV2T.TXT','R_MV2T.TXT','B_MV2T.TXT',
                  'E_MV2T.TXT','N_MV2T.TXT'/
C
C     TEMPERATURE TO MILLIVOLT FILENAME TABLES
C
      Data FILNY /'J_T2MV.TXT','T_T2MV.TXT','K_T2MV.TXT',
     *            'S_T2MV.TXT','R_T2MV.TXT','B_T2MV.TXT',
     *            'E_T2MV.TXT','N_T2MV.TXT'/
C
C     SELECTING MILLIVOLT/TEMPERATURE TABLES
C
     DO MM = 1, 8
      IF (KODE .LE. 8) THEN
         FILNT(MM)(1:16)  = 'DISK2:[ETFSUB77]'
         FILNT(MM)(17:26) = FILNX(MM)(1:10)
      ELSE
         FILNM(MM)(1:16)  = 'DISK2:[ETFSUB77]'
         FILNM(MM)(17:26) = FILNY(MM)(1:10)
      ENDIF
     ENDDO
C
C     OPENING SELECTED MILLIVOLT/TEMPERATURE FILE
C
     Do 100 MM = 1, 8
     IF (KODE .LE. 8)THEN
        Open (Unit=MM+10,File=FILNT(MM),Form='FORMATTED',
     *          Access='SEQUENTIAL',Status='OLD',READONLY,
     *          ERR=80,Iostat=IERR)
        PRINT *,' OPENING FILE=',FILNT(MM)
     GOTO 100
     ELSE
        Open (Unit=MM+10,File=FILNM(MM),Form='FORMATTED',
     *          Access='SEQUENTIAL',Status='OLD',READONLY,
     *          ERR=90,Iostat=IERR)
        PRINT *,' OPENING FILE=',FILNM(MM)
     ENDIF
     GOTO 100
C   CANNOT OPEN MILLIVOLT/TEMPERATURE FILES
C
80   Write (5,'('' ERROR OPENING INPUT FILE='',A)')FILNT(MM)
     GOTO 100
90   Write (5,'('' ERROR OPENING INPUT FILE='',A)')FILNM(MM)
100  CONTINUE
```

```
C
C       READING HEADER INFORMATION
C
        Read (11,'(A)') HEADER1
        Read (11,'(A)') HEADER2
        Read (12,'(A)') HEADER1
        Read (12,'(A)') HEADER2
        Read (13,'(A)') HEADER1
        Read (13,'(A)') HEADER2
        Read (14,'(A)') HEADER1
        Read (14,'(A)') HEADER2
        Read (15,'(A)') HEADER1
        Read (15,'(A)') HEADER2
        Read (16,'(A)') HEADER1
        Read (16,'(A)') HEADER2
        Read (17,'(A)') HEADER1
        Read (17,'(A)') HEADER2
        Read (18,'(A)') HEADER1
        Read (18,'(A)') HEADER2
C
C       BEGIN READING MILLIVOLT/TEMPERATURE ARRAYS
C       INDEPENDENT VARIABLES MUST APPEAR IN THE X-ARRAY
C
        II = 2
        DO MM =1,8
        IC(MM) = 1
130     Read (MM+10,*,End=140,ERR=145,IOSTAT=ICODE) X(II,MM,
     *        Y(II-1,MM)
        IC(MM) = IC(MM) + 1
        II = II + 1
        Go To 130
140     CONTINUE
        II = 2
        END DO
145     CONTINUE
        PRINT *,' ERROR WHILE READING INPUT FILES,
     *           ERROR CODE=',ICODE
148     CONTINUE
C
C       CLOSE INPUT FILE
C
        DO MM = 1,8
           IF (KODE .LE. 8) THEN
              CLOSE(MM)
           ELSE
              CLOSE(MM+10)
           ENDIF
        ENDDO
```

```
C
C       MOVE ALL VARIABLES INTO INDEPENDENT VARIABLE ARRAY
C
        DO MM = 1,8
           DO IV = 1, IC(MM) - 1
           X(IV+IC(MM),MM) = Y(IV,MM)
        ENDDO
        ENDDO
C
C       STORING NUMBER OF PAIRS
C
        DO MM =1,8
           X(1,MM) = IC(MM) - 1
        ENDDO
        RETURN
        END
```

Results

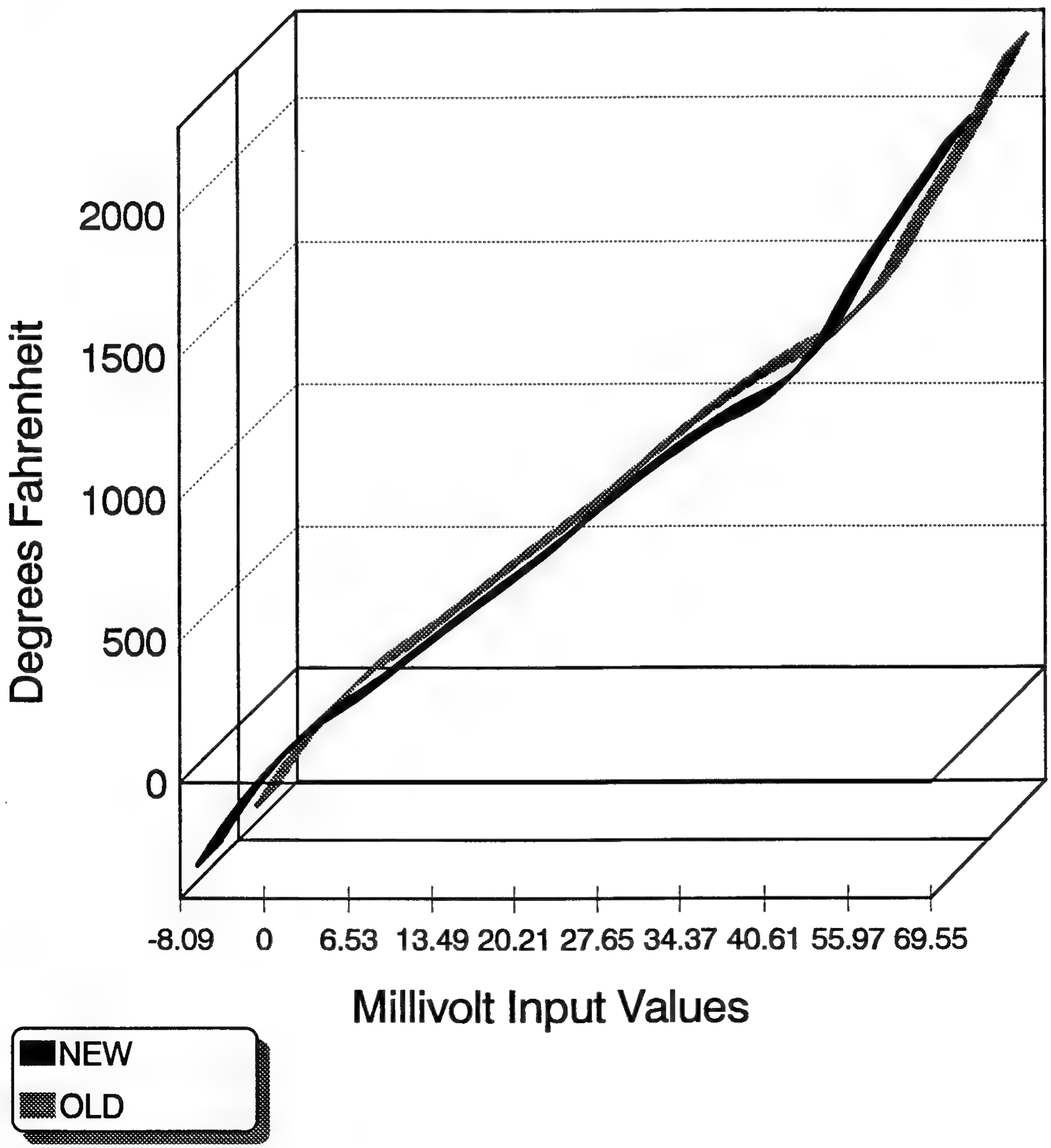
The results were accomplished within the tolerance that was suggested. This program, which uses the table lookup method to convert millivolts measured from thermocouples to corresponding degrees Fahrenheit, also converts degrees Fahrenheit to millivolts. The old "temperature function" was unable to do this. The results of the new "temperature function" are compared to the results of the old "temperature function" on pages 4-13, 4-14, and 4-15. The graphs on these pages only show results from type J, K and T thermocouples; however, both "temperature functions" operate on eight different types of thermocouples. The types of thermocouples in which the "temperature functions" operate are listed in the following table.

J = Iron vs Copper-Nickel (Iron-Constantan)
T = Copper vs Copper-Nickel (Copper-Constantan)
K = Nickel-Chromium vs Nickel-Aluminum (Chromel-Alumel)
S = Platinum vs Platinum-10%Rhodium
R = Platinum vs Platinum-13%Rhodium
B = Platinum-6%Rhodium vs Platinum-30%Rhodium
E = Nickel-Chromium vs Copper-Nickel (Chromel-Constantan)
N = Nickel-14%Chromium vs Nickel-4%Silicon

The results of converting degrees Fahrenheit to millivolts in types K and T thermocouples are shown on page 4-16.

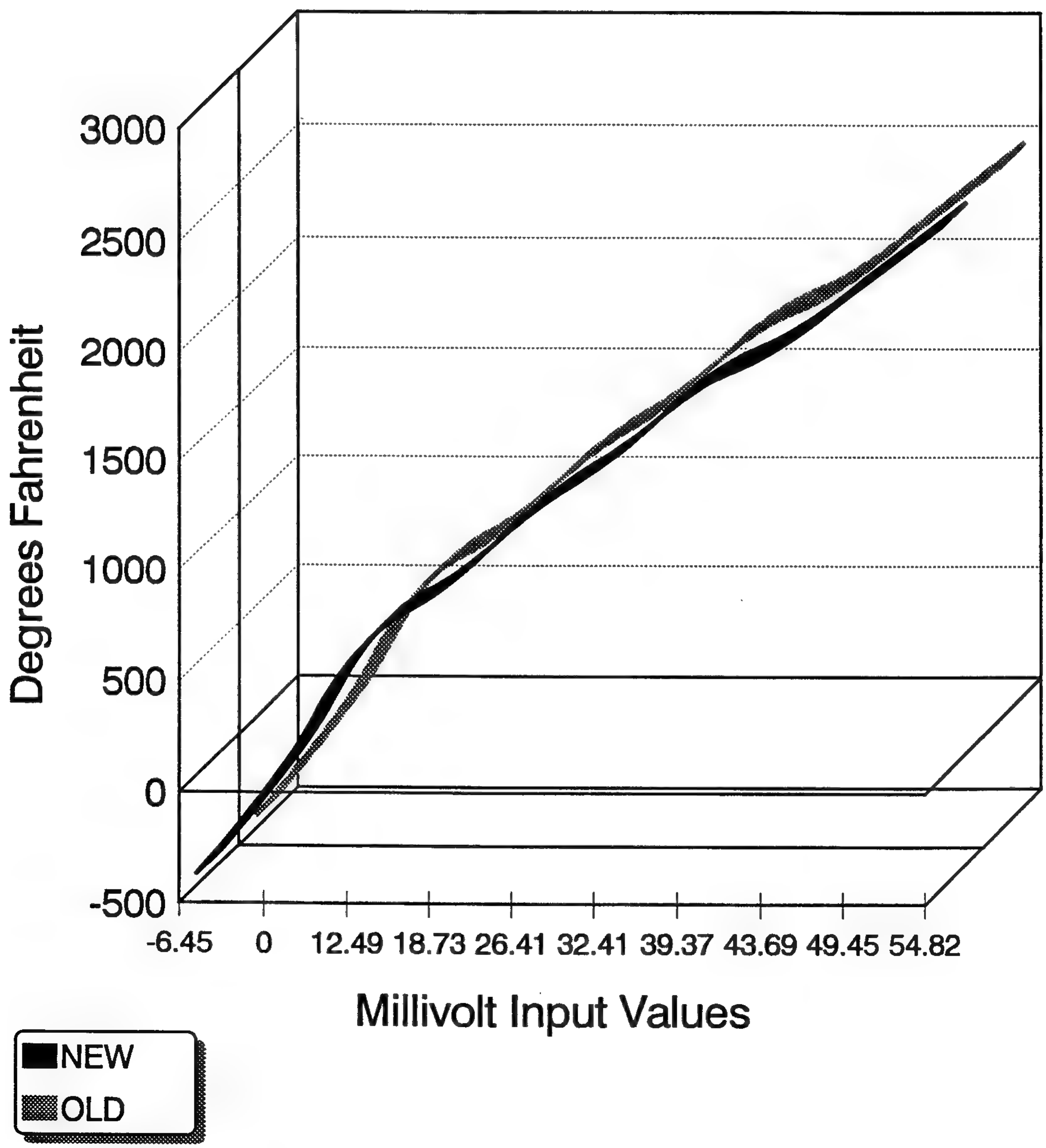
"TEMPERATURE FUNCTION" COMPARISONS

Type J Thermocouple



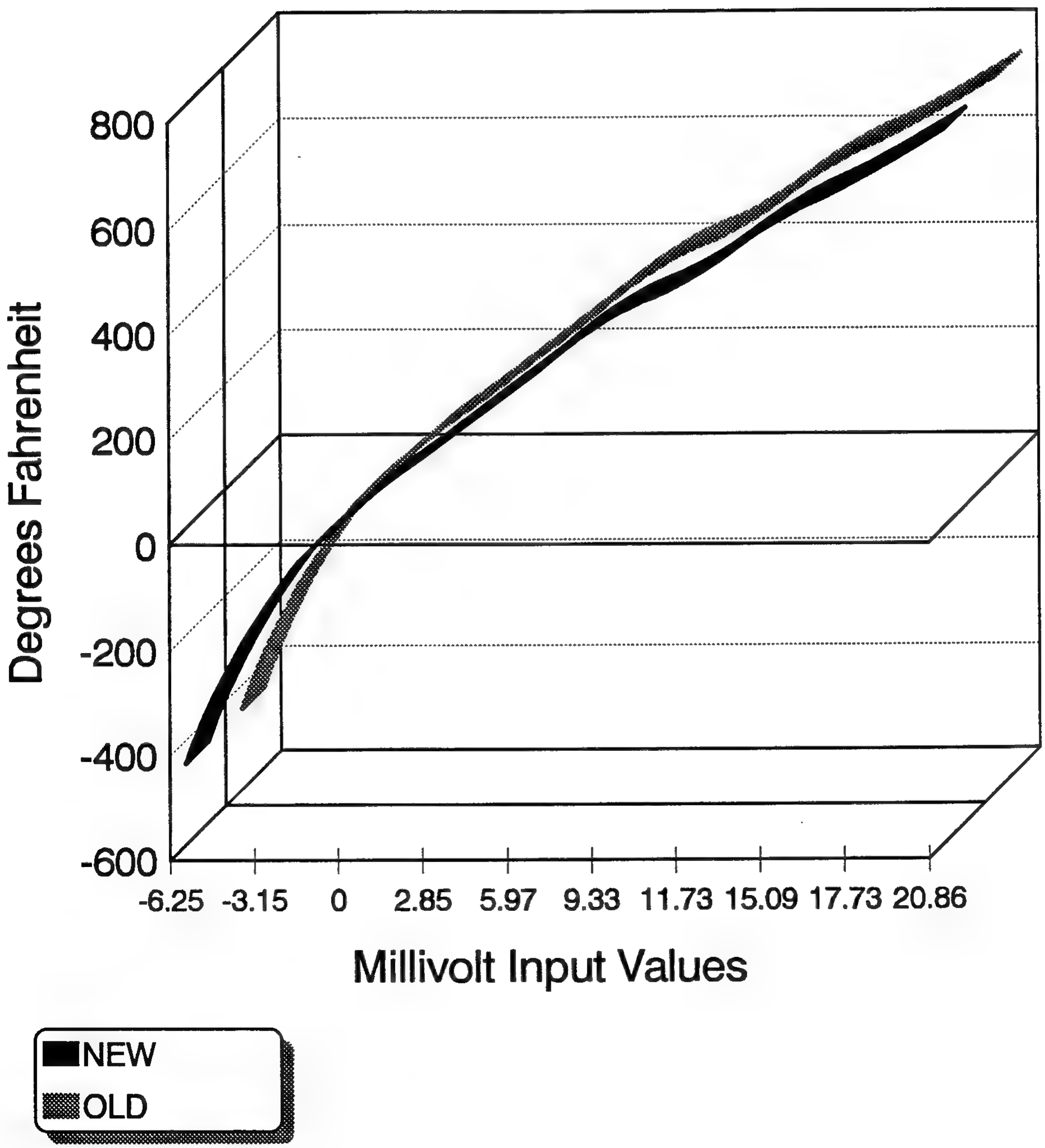
"TEMPERATURE FUNCTION" COMPARISONS

Type K Thermocouple



"TEMPERATURE FUNCTION" COMPARISONS

Type T Thermocouple



CONVERSION OF TEMPERATURE TO MILLIVOLTS
USING TABLE LOOKUP ROUTINE

Table of values taken from Type T thermocouple

INPUT TEMPERATURE	RESULT
-454.0	-6.45774
32.0	0.00000
568.2	12.12110
1074.6	24.02110
1470.6	33.24348
1907.4	42.89911
2149.8	47.97863
2498.0	54.81857

Table of values taken from Type S thermocouple

INPUT TEMPERATURE	RESULT
-346.0	-8.09538
32.0	0.00000
479.9	13.49043
698.5	20.20909
940.3	27.65097
1150.8	34.37114
1334.5	40.60895
2192.0	69.55318

Conclusion

In conclusion, the "new temperature function," which uses the table lookup method, achieves all the goals that were set at the beginning of this project. The "new temperature function" is more accurate than the previous way of conversion. The speeds of the two conversion methods are also comparable. Although it has yet to replace the "old temperature function," it is likely that this will occur soon. In summary, the function which incorporated the table lookup method using the methods previously described to convert millivolts measured from thermocouples to degrees Fahrenheit successfully completed all preliminary objectives.

ACKNOWLEDGMENTS

I would like to thank the Air Force Office of Scientific Research for giving me the opportunity to participate in this program. I also am very grateful to Tommie Heard and Jim McNeese for helping so much with my project and making this summer fun and interesting. Finally, I would like to thank James Mitchell for allowing the participants to get acquainted.

REFERENCES

1. "T/C EU Conversion Techniques for the Upgraded Data Acquisition System." Bennett, M.R. and T.L. Bradford. Jan. 21, 1994.

2. "Accuracy of EUD for Thermocouples." Mahrenholz, B.G. Aug. 3, 1993.

LIGHTING CALCULATION STUDY AND SOFTWARE EVALUATION

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Final Report for:
High School Apprenticeship Program
Arnold Air Force Base

Sponsored by:
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Bolling Air Force Base, Washington DC

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LIGHTING CALCULATION STUDY
AND SOFTWARE EVALUATION

Derek E. Geeting
Shelbyville Central High School

Abstract

Lighting systems and calculation techniques were studied. Several calculations were made by hand and compared to known solutions. Next, new software programs were used to recalculate the lighting systems. The results produced by the software were compared to the previous known solutions and hand calculations. One of the programs proved to be more accurate, quicker, and easier to use than the previously used hand calculations.

LIGHTING CALCULATION STUDY
AND SOFTWARE EVALUATION

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Introduction

In designing lighting systems for various facilities, the engineers at AEDC have always used traditional hand calculations to predict the amount of light that will be produced by their systems. This method has proved to be inaccurate at times and can also become a tedious project. A new way of making lighting calculations was needed. There are several lighting software programs available, so it was decided that one should be acquired that would produce better results. My task was to evaluate some of the programs to determine if any could be used instead of the older methods.

Methodology

The first step in approaching the project was to learn how lighting calculations are made. There are many factors to consider in deciding which type of lights to use. Cost is one of the main factors. Not only are some lighting systems expensive to purchase, but maintenence cost is sometimes the most restricting factor. To ensure maximum output from the lights, they must be kept clean, turned on at the appropriate times, and fed a steady power supply. Environmental restrictions are also an important factor. Most lights should be disposed of in special ways to ensure a safe environment. Having these lights destroyed or recycled in the proper manner can cost more money than it takes to purchase them. Life expectency can change the efficiency of a system as well. The lights chosen must produce enough light to amply illuminate the specific area, too. A list of ANSI lighting level standards was used to determine how many footcandles (the English unit of illuminance) were needed in each area surveyed. Also, the reflectance of the light off the ceiling, walls, and floor was used to determine how much light would be produced. Another factor

was the color temperature given off by the fixtures. The color of the light has been proven to affect the productivity levels of workers because of unnoticed eyestrain and psychological effects. There are three main types of lights considered when redesigning a lighting system. These are incandescent, fluorescent, and high intensity discharge (H.I.D.) lamps. Incandescent lights burn a filament to produce light. These are the type of lights used in most homes. Fluorescent lights are actually tubes filled with gases, usually noble gases such as argon, which are excited by electricity on both ends of the tube. These are the most popular in office areas. They are relatively efficient and produce the desired lighting level for that type of environment. The H.I.D. lamps were used mostly in this project because of their capabilities in producing a high level of light. The three main types of H.I.D. lamps are mercury vapor, metal halide, and high pressure sodium. The metal halide lamps were preferred because of their low cost and superior output. High pressure sodium lamps are more environmentally safe, but they are more expensive and don't produce results as good as metal halide lamps. Once all of these and other factors were taken into consideration, some hand calculations were made on various facilities where the results were already known in order to test the methods currently being used. Next, the calculations were ran on the software program, and the results were compared. In calculating these results by hand, an estimate of .75 was used as the coefficient of utilization (CU), an important variable used in the calculation. An accurate CU value can be obtained through the hand calculation method, but it is a time consuming process. In the software program, an accurate value of the CU is obtained with no extra effort on the part of the user. Other variables such as reflectance and light level depreciation factors were estimated in both methods because of the ease in determining a reasonably accurate value. After determining which software program was best, practical application was made with the software on several facilities in need of lighting retrofits.

Results

After comparing the results produced by the software program and the hand calculation method, it was decided that the software program was a better method of making lighting calculations. The CU estimate of .75 was found to be a good estimate, but the deviation of the estimate from the precise value determined by the software program was

enough to make a notable difference in the final lighting decisions. The software proved to give a more accurate description of the lighting level or number of fixtures needed in making lighting calculations. Also, it offered the convenience of quick calculations and more advanced options, too. The program allows the user to place the lights in any position desired instead of only an array of rows and columns. In order to do this by hand several calculations must be performed and an accurate result is difficult to obtain. Another useful option that the program has is a detailed economic analysis of the cost and maintenence of the lighting system over its period of use. This is a multi-step procedure in hand calculation.

Conclusion

After a detailed evaluation of the software program, Softlite, it was decided that its use was a much more efficient way of making lighting calculations. The program will be used in future lighting projects at AEDC in place of the hand calculation method and other software.

THE USE OF LABVIEW FOR SERIAL DATA TRANSMISSION

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Franklin County High School

Abstract

The application of Labview to serial communications was studied. The subject of the experiment was a Sony Hi8 mm videocassette recorder , on loan from the Plume Data Center video lab at Arnold Engineering and Development Center. A personal computer was connected to the VCR by a standard RS-232 line to allow serial data transmission. A Panasonic video camera and a Sony monitor were also attached to the VCR, the camera for input and the monitor for display. A program using Labview was written to remotely control the VCR. This system allowed the computer to control the basic functions of the videocassette recorder.

THE USE OF LABVIEW FOR SERIAL DATA TRANSMISSION

Jennifer A. Groff

Introduction

Testing machinery, rockets, jet engines, etc. is a very costly form of study. Because of this, the tests are recorded on video to allow further and more intense research. The video equipment, controlled by a computer or a system of computers, offers a more accurate form of study.

Discussion of Problem

Several audio-visual instruments are often used at the same time. They are also used in dangerous places for humans. Therefore, computers are generally used to control the various instruments. Computer interfacing allows a more accurate, and often easier, form of control. A general program was needed to remotely control the basic functions of a VCR.

Methodology

The method of controlling an instrument with serial communications is by writing a program on a PC to send and interpret messages. In this particular case, Labview was used. Labview is a program in which VI's, or virtual instruments, are used. Virtual instruments are simulations. They consist of user interfaces, which allow interactive control of the software system. The front panel is the interactive interface, created by the user, made of switches, knobs, slides, etc. The user also creates the block diagram. The block diagram is the actual program, made up of functional blocks, or subroutines, represented by icons. The icons, also referred to as subVI's, are wired together to pass data from one block to another {2}. In this manner, a program was formed for controlling the VCR.
To use this program, the computer was connected to the Sony Hi8 by using an standard RS-232 serial connector cable. Also attached to the VCR was a Panasonic video camera for input and a Sony monitor for display. Serial data transmission, sending bits down a single wire one after another, was used for this project {1}.

Results and Conclusions

The resulting program is constructed as follows:

FRONT PANEL :

1) The buttons for the basic commands and the editing commands are arranged in a cluster.
2) A shuttle (rewind/fast forward) is a knob positioned beside the cluster {3}.

BLOCK DIAGRAM :

1) The basic command buttons and the editing command buttons have been given numbers within the cluster. The cluster of commands is sent to a conversion VI that changes it to a Boolean (T/F) array of LED's. The output of the array is connected to the Search 1D Array VI. Here the array is searched for a "true" constant. The output of the Search 1D Array is a number of the command button pressed within the cluster, 0-10 {3}.

2) The numeric output is sent to two places: the Index Array VI and a numeric indicator. At the Index Array VI, the number meets with a string array of the basic and editing commands in hexadecimal code. These hexadecimal commands also have assigned numbers that coincide with the command button numbers. The Index Array VI matches the button numbers to the code numbers. When the codes and buttons are matched, the code is sent to a string indicator. From the indicator, the information is sent to a case statement {3}.

Before the case statement can execute, however, the numeric output of the Search 1D Array VI must be sent to the numeric indicator. From the indicator, the number is compared to 0. If it is greater than or equal to 0, the case statement will read "True." If the number is less than 0, there is an error and the case will read "False." The false case is empty, so the program stops. The true case is the process by which the commands are sent to the VCR. Inside the "True" case, the serial port (0) is established. An error handler is connected to the serial port Inititialize VI. If no errors occur, a second case statement within the first will read "False." If there is an error, the case will be the empty set, "True." In the false case, there is a sequence structure. The first frame of the sequence writes the hexadecimal code output from the Index Array VI to the VCR. The second frame reads the present byte count and sends that count to the next frame using a structure called a sequence local, which is a storage area for information. In the third frame, the byte count is set and the information from the VCR is read back to the computer {3}.
A basic or editing command can be executed using the previous system.

3) To use the shuttle, a different system is used. From the numeric indicator, the number is sent to a while loop. Inside the while loop, the output is compared with the constant number 4. The number 4 is the button and code number for the command "PLAY"; the shuttle is only used in the "PLAY" mode. If the output number is equal to 4, the case statement inside the loop reads "True." If the number does not equal to 4, the case is false and the loop, in theory, terminates. In the true state, the shuttle hexadecimal codes and shuttle control numbers are sent to the Index Array VI. Here, as before, the numbers are searched for matches. The hexadecimal code is sent to a string indicator, which feeds the code to a sequence structure. This sequence structure carries out the same steps as the one mentioned earlier: writes input to the VCR, sets the byte count, and reads the output from the VCR {3}.

4) All of the previous systems are enclosed in a large while loop to keep the program continuous.

The program functions relatively well, with a few problems. The shuttle does not execute correctly every time, but the basic and editing commands are very dependable. These commands will hopefully be helpful in future testing environments.

REFERENCES

{1} Gofton, Peter W. Mastering Serial Communications. SYBEX, Inc.: San Francisco, 1986.

{2} National Instruments. IEEE 488 and VXIbus Control, Data Acquisition, and Analysis. National Instruments Corporation: 1993.

{3} National Instruments. Labview for Windows Full Development System. National Instruments: Austin, 1993.

ACKNOWLEDGMENTS

Jeffrey Ready for his help and encouragement as my mentor;

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Anthony Alford for his help on the project;

finally, Don Gardner for his help on my presentation for the other students, parents, friends, etc.

OUT OF BAND FILTER CALIBRATION TECHNOLOGY PROJECT

James Lemmons

Coffee County Central High School
Manchester, TN

Final Report for:
High School Apprentice Program

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Bionetics Corporation
AEDC

August 1994

OUT OF BAND FILTER CALIBRATION TECHNOLOGY PROJECT

James Lemmons

Abstract

A new calibration procedure was needed for filters from the Plume Data Center . These filters have to be calibrated precisely through several orders of magnitude. Light from two sources was used to get all the wavelengths of light fom 800nm down to 200 nm. The light was passed through a diffraction grating spectrometer and into the detectors. Three different detectors were tested for their linearity to find the one with the best range. Many experiments were run checking the linearity of the detectors. The solution was to use different detectors over different parts of the wavelength range and combine them to make one calibration.

OUT OF BAND FILTER CALIBRATION PROJECT

James Lemmons

Introduction

Bandpass filters are used in optics to allow only a small group of wavelengths to transmit. Most bandpass filters used today are thin film stacks based on quarter wave optical filter theory. These quarter wave thin film stacks become additive or subtractive by the phase interaction of the wavelengths of the source light, (Macleod 1969). One main problem with quarter wave thin film filters is the blocking ability of the filter at harmonic wavelenghts of the passband. In order to eliminate this problem optical manufactors vary the stack thickness and add numerous stacks (400 or more) to improve blocking. Even so blocking ability of filters from the same manufacturer can vary in the hundreds of percent.

Discussion of Problem

A more accurate calibration method was needed to support the Plume Data Center. The Plume Data Center uses radiometers and spectrometers to analyse rocket plumes in the UV region of the spectrum. Energy from the visible light can produce large errors in the UV energy measurements. Bandpass filters in the UV are used to block all visible light but pass the UV wavelengths of interest. The amount of leakage by the filter in the visible region is difficult to calibrate and is not accurately done by regular commercial optical companies. The calibration lab (PMEL) was given a technology program to develope and quantify transmission of blocking filters over eight orders of magnitude.

Experiments were conducted on three calibrated detectors to determine the linearity error each produced over its dynamic range. The setup used two adjustable irises in front of the collection optics to change the input power into the spectrometer without changing the path length or spectral content of the lamp energy. The actual experimental setup is shown in Figure 1.

Methodology

In order to determine the linearity of the detectors over the 200nm-800nm range, experiments were conducted which varied the power through the spectrometer linearly and without spectral variation. In

figure 2 the setup diagram shows two adjustable irises which were changed to calibrated diameters of 1/16", 1/8", 1/4", 3/8" and 1/2". This allowed each decade of detector response to be compared to a NIST traceable calibration of the detector response. Since only the power at the detector changed any spectral change in output was a measure of linearity error. In other words the spectral responsivity curve shape of the detector should not change with simple power variations.

After all the linearity experiments were conducted the next task was to identify types and sources of error in the measurements. The first source of error was in the lamp sources. Both type sources, deterium and DXW-1000, have been evaluated in the past. Short term stability of a deterium lamp is within 2%, short term stability of a DXW lamp is within 1% based on a 95% confidence interval. Other primary sources of error are in the double diffraction grating spectrometer. The spectrometer leakage is specified by the manufactor at below 8 orders of magnitude in the 200nm-800nm ranges. However, the laser check indicated a fixed leakage at 632nm of 0.0005%. This number will be used as a bias error in the calibration. The detectors represent the greatest error in the uncertianty annalysis for which the primary experiments indicated. The lock-in amplifier and pre-amp were also evaluated by the Electrical Standards Lab (PMEL). This error was less than 2% maximum over the DC dynamic range of the system.

To compute the uncertianty of all the errors the classical RSS formula was used:

U =SQR(U1^2 + U2^2 + U3^2)

for the lamp error, detector and lock-in amplifier error. The spectrometer leakage should then be added to the RSS error as bias error as shown here:

U total = SQR(U1^2 + U2^2 +U3^2) + U spectrometer

Results

Data from the detector experiments are shown in Figures 3-4. The first graph indicates the three detector errors in the UV from 200nm to 300nm. The second graph indicates the results of two detectors from 300nm to 800nm. Note, all linearity error has been normalized to percent of maximum in dynamic range. This conversion from simple current level ouput of the detectors simplifies unceritanty calculation for filter calibrations.

The last experiments used an actual bandpass filter from the Plume Data Center to evaluate the actual

capability of the system using all three detectors. Using the linearity error charts shown in Figures 3-4 it determined that only the Solar Blind PMT and Silicon detector are nessary to calibrate a bandpass filter with the least error. Figure 5 shows the results of combining the solar blind PMT scan of the UV and the silicon detector scan of the visible. The estimated uncertianty of each decade of measured transmission is shown on the chart in Figure 6.

Conclusion

The detector experiments indicate a usable calibration method for PMEL to incorporate into a standard airforce calibration. The actual uncertianty of this calibration method over the large dynamic range will need to be verified by a higher lab, such as NIST or AGMC.

BANDPASS FILTER CALIBRATION SETUP

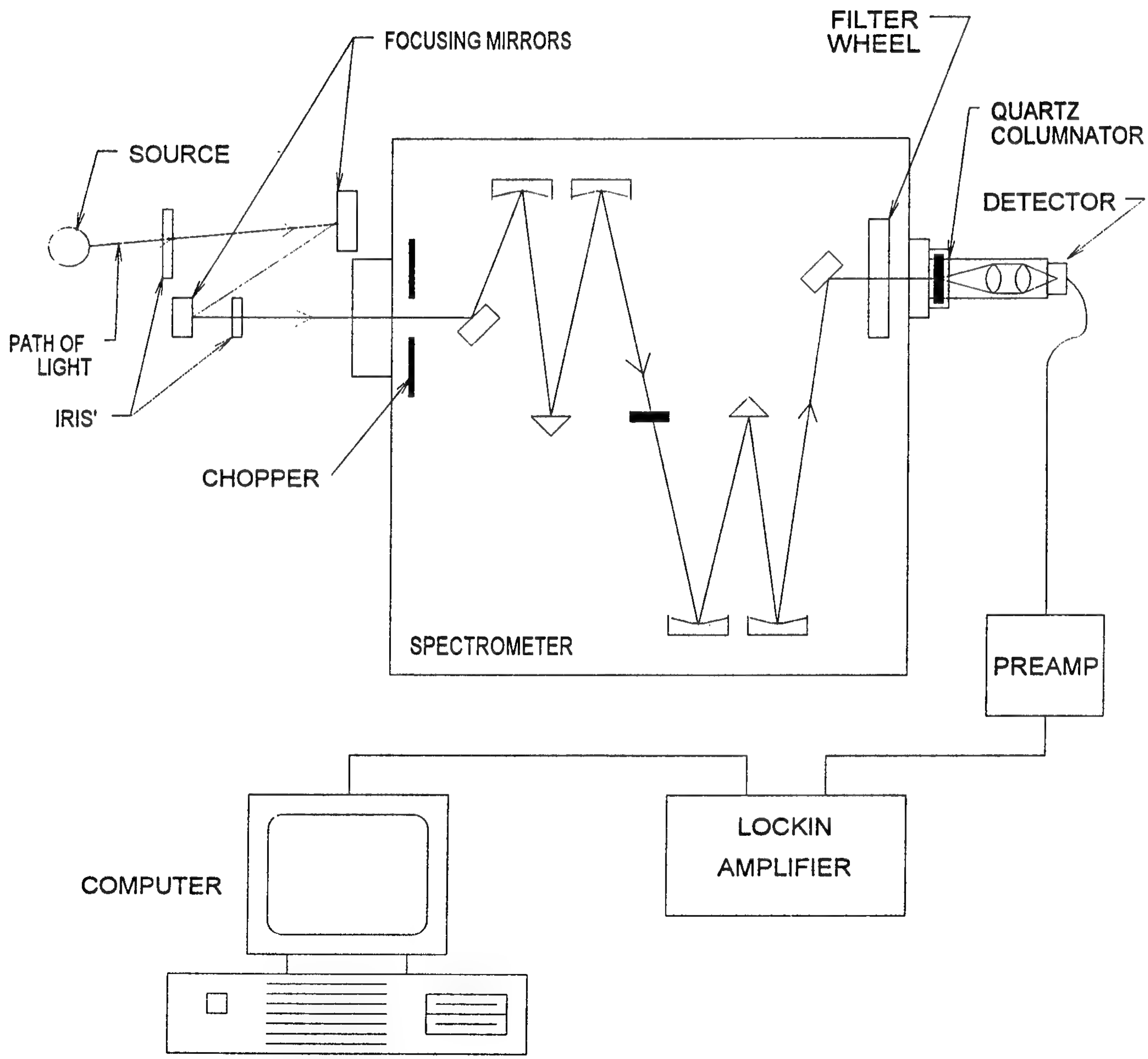

FIGURE 1

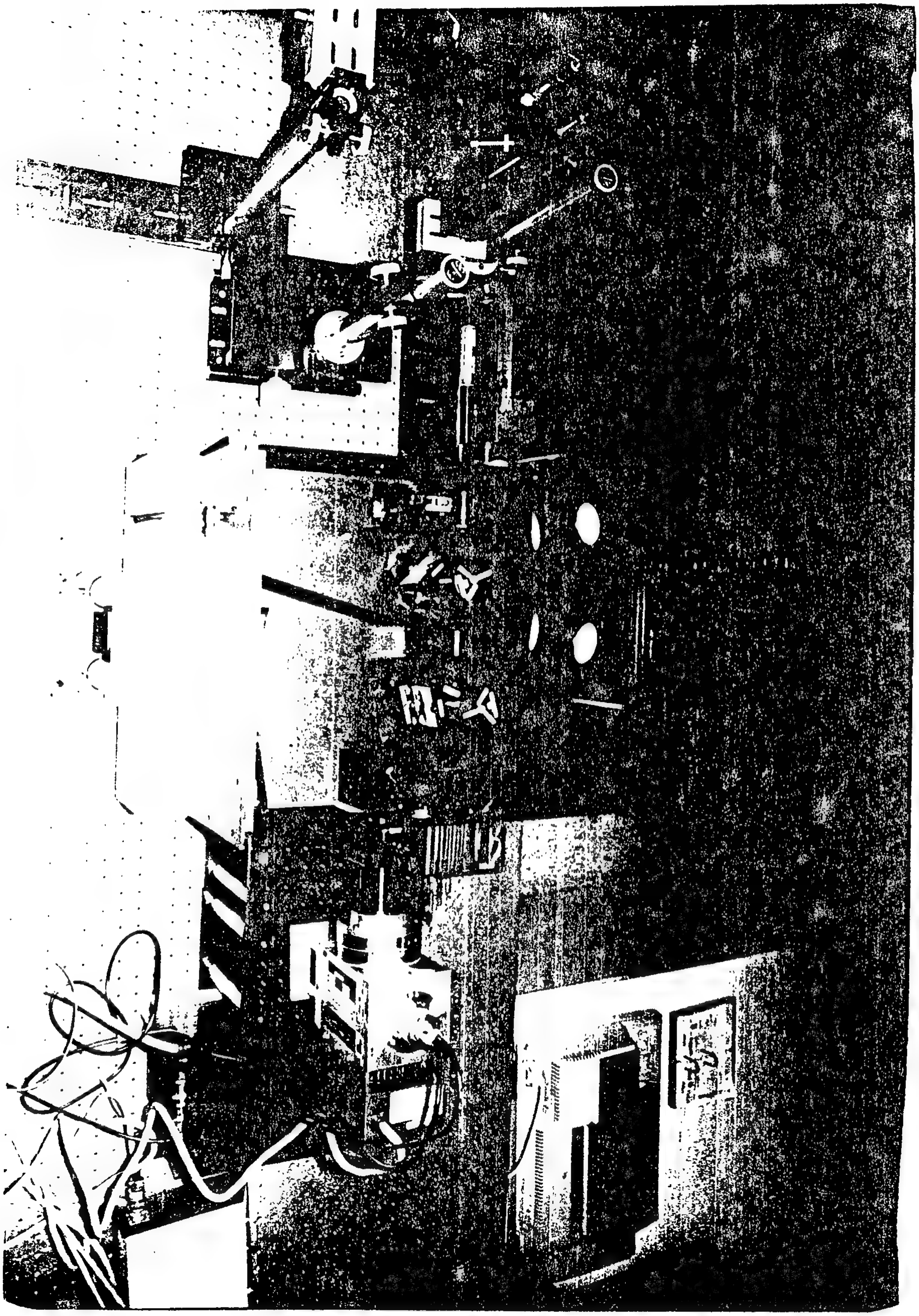

FIGURE 2

LINEARITY ERROR UV RANGE

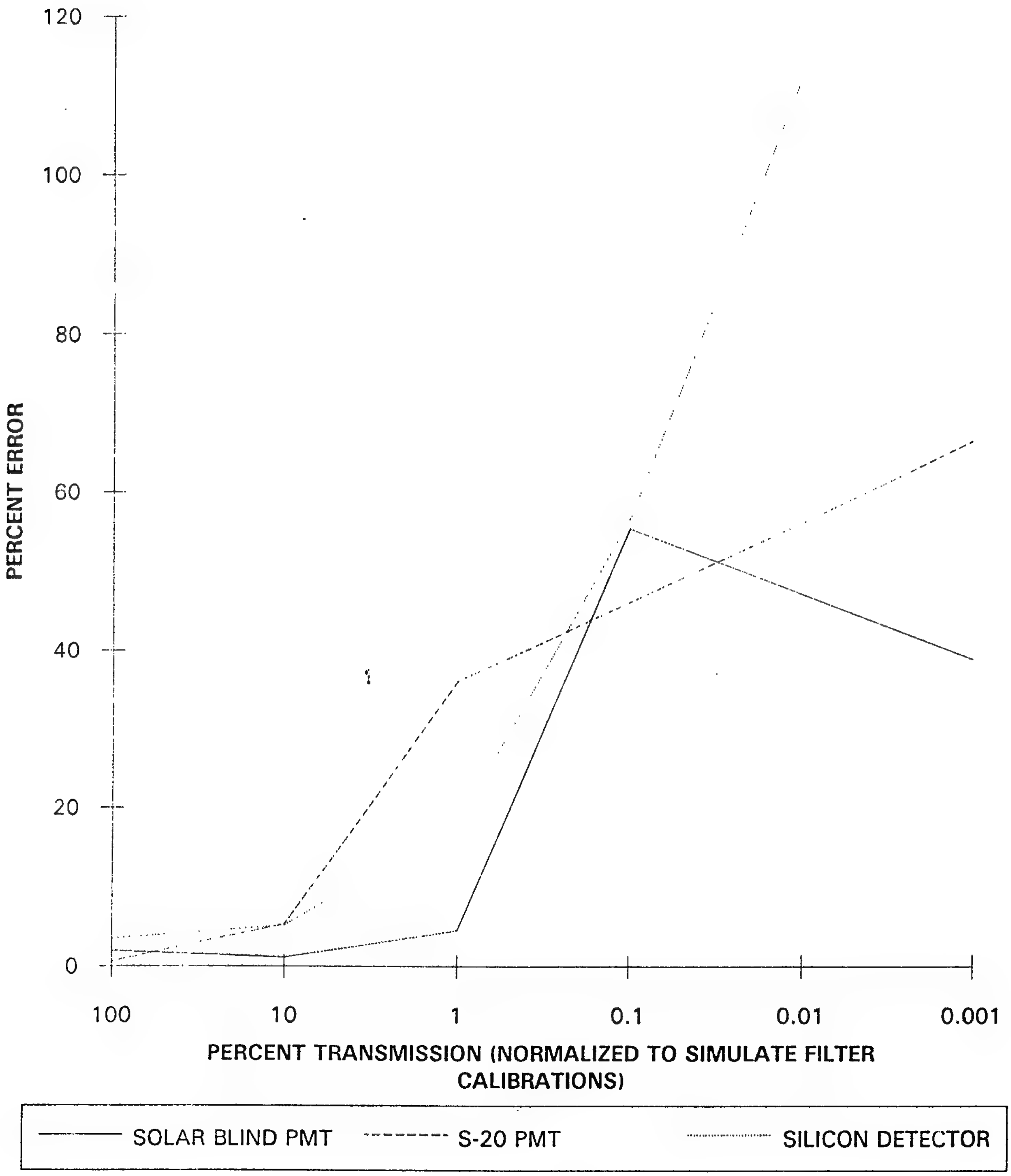

FIGURE 3

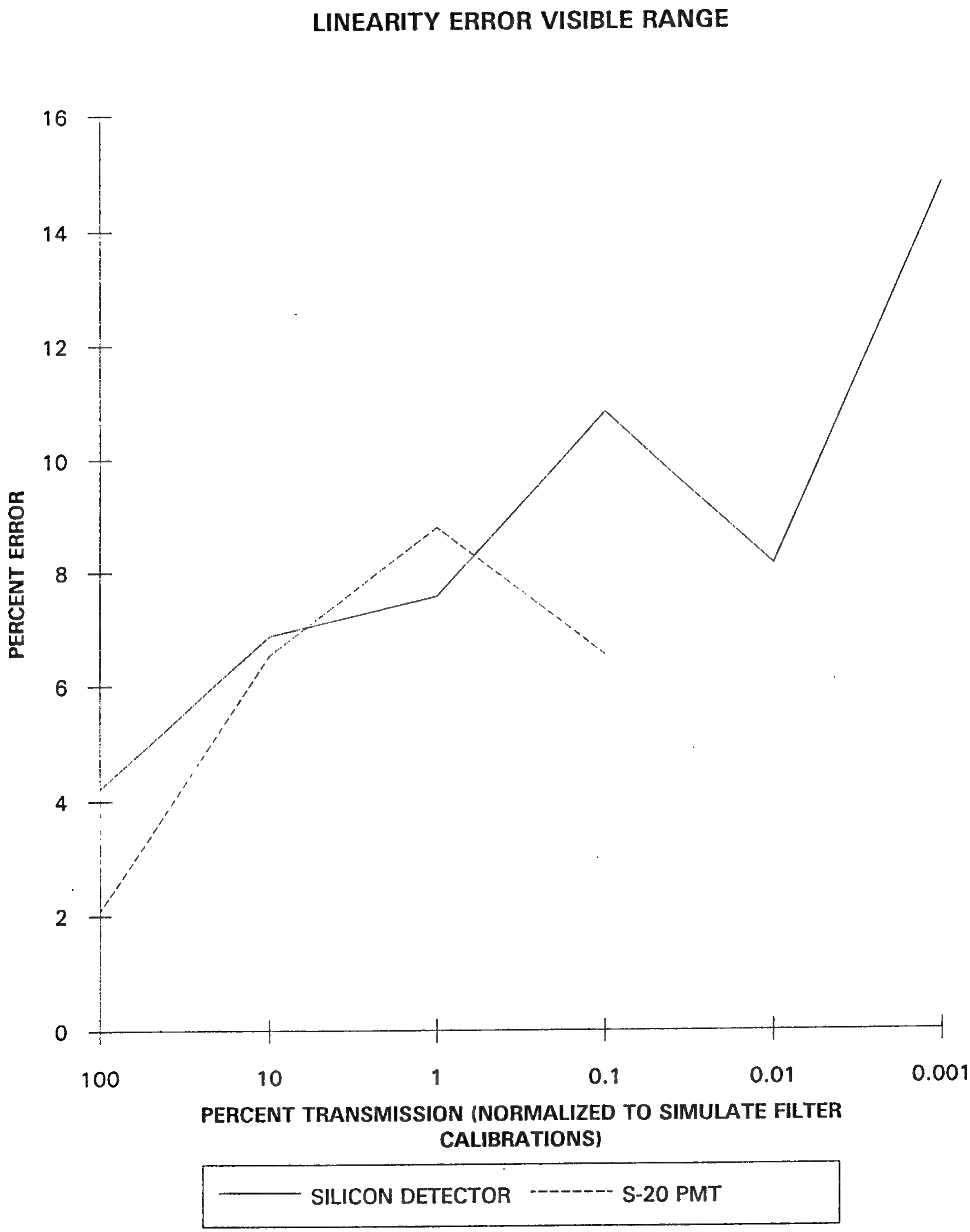
LINEARITY ERROR VISIBLE RANGE
PERCENT ERROR
16
14
12
10
8
6
4
2
0
100
10
1
0.1
0.01
0.001
PERCENT TRANSMISSION (NORMALIZED TO SIMULATE FILTER CALIBRATIONS)
SILICON DETECTOR
S-20 PMT

FIGURE 4

PLUME DATA CENTER FILTER CALIBRATION

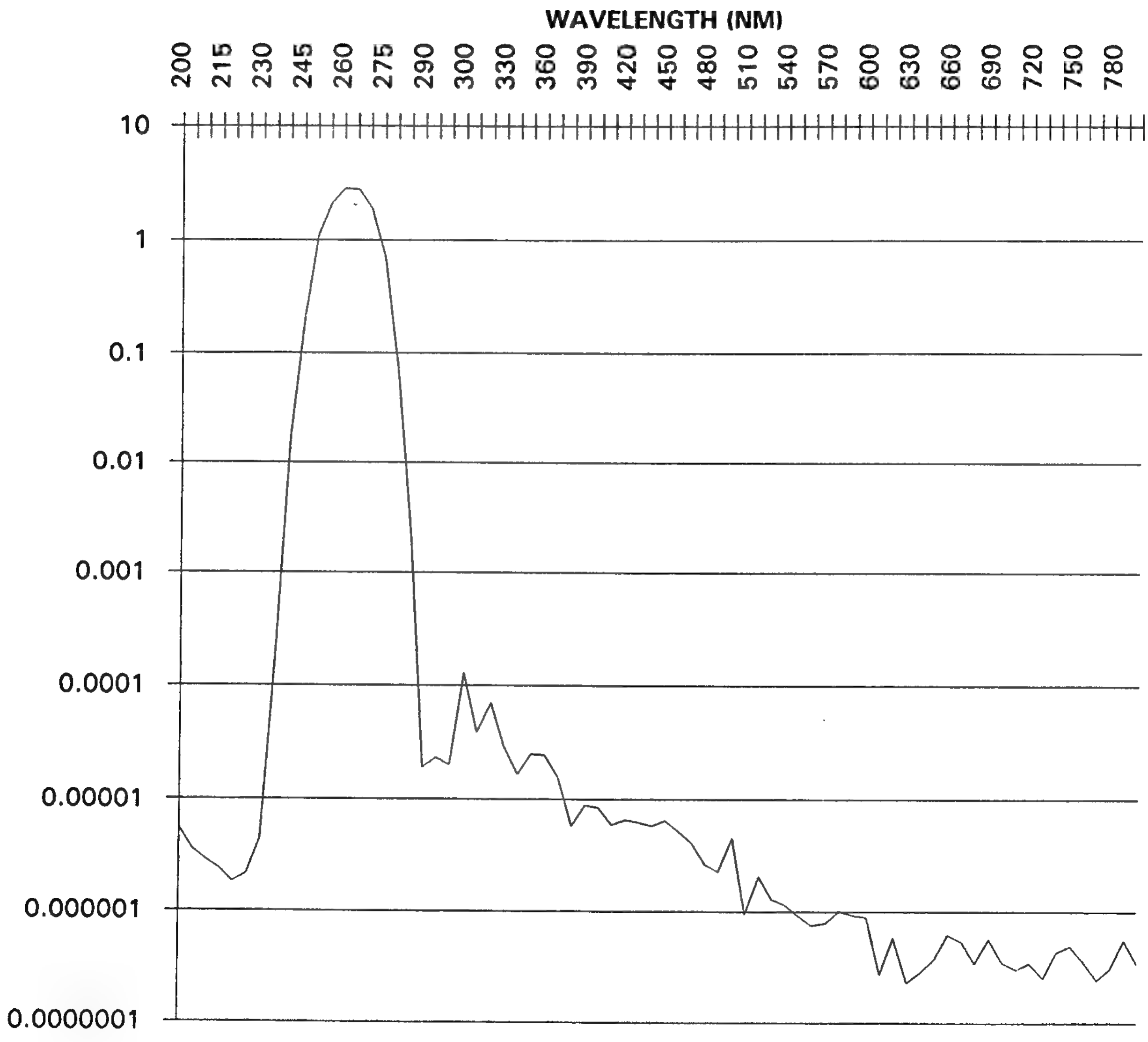

FIGURE 5

PROJECTED UNCERTIANTY

TRANSMISSION	UV RANGE 200-300NM	VISIBLE RANGE 300-800NM
100	3.60%	4.10%
10	3.60%	7.10%
1	5.30%	7.10%
0.1	55.50%	9.50%
0.01	60%	11.50%
0.001	105%	65%

FIGURE 6

REFERENCES

Thin-film Optical Filters. H. A. Macleod: McGraw-Hill Publishing, 1989.

University Physics Part II : Addison-Wesley Press, 1992.

Microsoft Excel User's Guide. Microsoft Corporation, 1992.

A STUDY OF HYDROCARBON COMBUSTION: STOICHIOMETRY VS. EQUILIBRIUM

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August 1994

A STUDY OF HYDROCARBON COMBUSTION: STOICHIOMETRY VS. EQUILIBRIUM

Lana Matthews
Coffee County Central High School

Abstract

The combustion of various hydrocarbons with oxygen was studied. By creating a computer program in the FORTRAN programming language to compute stoichiometric data and by using TEP (Thermo-chemical Equilibrium Program) to provide data at chemical equilibrium, data from combustion of methane, ethane, propane, butane, ethylene, and acetylene with oxygen was computed and plotted with equivalence ratio for both lean and rich conditions. For very lean combustion, the stoichiometric temperature agreed with the equilibrium temperature. For combustion near stoichiometric conditions the equilibrium temperature was depressed, due to dissociation of carbon dioxide into carbon monoxide. For very rich combustion, all fuels except methane exhibited exothermic dissociation to some degree. Actually, when plotting temperature with equivalence ratio of acetylene, the equilibrium temperature became much higher than the stoichiometric temperature as the mixture got richer. Considering the multiple bonds in acetylene, the reason for the larger margin was attributed to the exothermic dissociation of acetylene into carbon, hydrogen, and methane in equilibrium. When the mole fraction of carbon dioxide was plotted versus equivalence ratio for the six gases, an unexpected "double hump" in all but acetylene was observed in equilibrium. After further plotting and the consideration of the dissociation of carbon dioxide, it was concluded that the competition for oxygen played the major part in the irregular increase of the mole fraction of carbon dioxide.

A STUDY OF HYDROCARBON COMBUSTION: STOICHIOMETRY VS. EQUILIBRIUM

Lana Matthews

Introduction

Scientists have used rockets for many years to explore our universe. A rocket is launched when a combustion reaction takes place in the chamber where a fuel and an oxidizer are sparked at a high temperature, high pressure, and low velocity. The explosion is forced through a small opening called the throat, where the conditions are converted to a low temperature, low pressure and high velocity. It then moves through the nozzle and is thrust outside to form the plume (Figure 1). By studying the reaction in the chamber, the behavior of different fuels and their resulting products can be explained.

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Methodology

The difference between the stoichiometric and equilibrium results of the reactions were to be plotted. Stoichiometry is the means by which a reaction's equation can be solved using specified products. The products used are equally balanced for both sides of the equation. For hydrocarbon combustion, the assumed products are typically carbon dioxide and water. When using stoichiometry, many products that are actually produced, although sometimes only in minute quantities, are not accounted for. For hydrocarbon

combustion, these products include carbon monoxide, hydroxyl, and lower hydrocarbons. In an equilibrium reaction all products that are produced, regardless of the amount, are considered, and the equation is balanced accordingly. In order to gather the data necessary to plot the results of the stoichiometric reactions, the molar and mass stoichiometric oxidizer to fuel ratios and the general oxidizer to fuel ratios by mole and mass had to be calculated for the equation of the reaction. The equivalence ratios were then found for the conditions needed. Equivalence ratio indicates how "rich" or "lean" the mixture is. If it is greater than one, the mixture is rich in fuel. If it is less than one, it is lean in fuel. The general oxidizer to fuel ratios by mole and mass were found by using a general hydrocarbon combustion reaction equation.

$$C_xH_y + aO_2 \rightarrow bCO_2 + dH_2O + eO_2 + fC_xH_y \qquad (1)$$

Variables "b," "d," "e," and "f" were found as a function of "x," "y," and "a."

Lean conditions:	**b=x**	**Rich Conditions:**	**b=x-fx**
	d=y/2		**d=y-fy/2**
	e=a-x-y/4		**e=0**
	f=0		**f=x-b/x**

The equation was solved in terms of "a" in order to find the ratios.

$$\mathbf{O/F_{mole} = a \quad and \quad O/F_{mass} = 32a/12x + y}$$

For equivalence ratio equal to one: e = f = 0

Gases contain both thermal and chemical potential energy. Combustion converts the chemical energy of the fuel into thermal energy. Since energy is conserved, all the chemical energy of the fuel is transferred to the products as thermal energy, resulting in a high temperature. The equation for conservation of energy can be written as:

$$\sum_{reactants}\left[\upsilon_i'\left(h_f^0 + \int_{T_{ref}}^{T_r} C_p dT\right)\right] = \sum_{products}\left[\upsilon_i'\left(h_f^0 + \int_{T_{ref}}^{T_p} C_p dT\right)\right] \qquad (2)$$

$$h_f^0 = chemical\ energy; \quad \int_{T_{ref}}^{T} C_p dT = thermal\ energy;$$

υ_i = *stoichiometric coefficients*

All variables on the left hand side are specified. The stoichiometric coefficients on the right hand side are found from equation (1) when considering stoichiometry. Therefore, the only unknown on the right hand side is **Tp**, the temperature of the products. This was found in the FORTRAN program by iteration. When considering equilibrium, the stoichiometric coefficients must also be found iteratively. This was computed by the TEP program.

All calculations (for the lean side only) were used to write a FORTRAN computer program that provided the needed stoichiometric data for the six gases. These gases included methane, ethane, propane, butane, ethylene, and acetylene. The equilibrium results were computed by using TEP. Plots were made to compare the stoichiometric and equilibrium conditions for both temperature and the mole fraction of carbon dioxide. The percentage of carbon dioxide dissociated in equilibrium was also plotted for the six gases. As the mixture becomes richer in fuel, a competition for oxygen takes place. Carbon dioxide is usually dissociated into other products, mainly carbon monoxide. Once the results from the lean side were completed the computer program was changed to suit conditions from both the lean and rich sides. New plots were made considering equivalence ratios ranging from 0.01 to 100.

<u>Results</u>

Temperature, mole fraction of carbon dioxide, and the percentage of carbon dioxide dissociated were plotted versus equivalence ratio for the lean side only, using both stoichiometry and equilibrium. The percentage of carbon dioxide dissociated is the amount of carbon dioxide that is decomposed to form other gases. This is defined as:

$$\textbf{\% CO}_2\textbf{ dissociated} = X_{CO}/X_{CO} + X_{CO2}, \quad (3)$$

where X's represent mole fractions

Both the stoichiometric temperature and the stoichiometric mole fraction of carbon dioxide was considerably higher than the equilibrium of either (Figures 2 and 3). There was a slight increase in the difference of the two as methyl groups were added to make different fuels. Ethylene and acetylene showed the biggest difference, however, due to the fact that they have added bond order. The added bond order allows the fuel to store more chemical energy, giving the fuel a larger energy increase. The percentage of carbon dioxide that would be dissociated in the reaction remained virtually the same for all fuels except acetylene, which, because of the high temperature, dissociates more carbon dioxide into various products, particularly carbon monoxide (Figure 4). The dissociation of carbon dioxide into carbon monoxide absorbs energy, and therefore lowers the equilibrium temperature.

The results that came from the rich side were different than those from the lean side. Since the equivalence ratio was taken all the way to one hundred in the plots, the conditions were very extreme.

When looking at the stoichiometric and equilibrium plot of temperature, an unexpected result was noted as the equivalence ratio increased. Instead of the temperature continuing to drop, at a certain point for each fuel it leveled off and crossed over the top of the stoichiometric line (Figure 5). The "crossing" appeared in all gases, although acetylene, by far, possessed the greatest difference in equilibrium and stoichiometric temperature (Figure 6).

The fact that the equilibrium temperature of acetylene exceeds its stoichiometric temperature can be explained by simply examining the number of products it produces. A fuel percentage of one hundred was ran on TEP, and the products that each gas dissociates into are given in Table 1. Essentially, in extremely rich conditions, acetylene does not want to exist as acetylene. The other five gases (methane, ethane, propane, butane, and ethylene) are fairly stable and dissociate only slightly in equilibrium. On the

other hand, acetylene dissociates almost completely. These extra products, though in small amounts(except for acetylene), are not accounted for in the stoichiometric calculations. This dissociation is exothermic; therefore, the equilibrium temperature is increased.

Still on the rich side, plotting the mole fraction of carbon dioxide also produced an unexpected result. As the equivalence ratio exceeded one, the mole fraction decreased as expected. As the equivalence ratio continued to increase, though, the carbon dioxide reached a point where it started to go back up, and then it came back down to form what looks like a "double hump" in the equilibrium line (Figure 7). All six gases that were plotted followed the pattern except acetylene (Figure 8).

In searching for an explanation of the "double hump" in the equilibrium mole fraction of carbon dioxide, a single plot was made using the mole fractions of carbon dioxide (X CO2), carbon monoxide (X CO), and carbon graphite (X C(Gr)) (Figure 9). The plot revealed that at the point where the carbon dioxide began to increase again, the carbon monoxide began to decrease and the carbon graphite also stopped increasing and began to level off. In a competition for oxygen in those extreme conditions, carbon dioxide is regaining oxygen from carbon monoxide, and it is taking carbon from the carbon graphite. This causes the amount of carbon dioxide to increase. As the equivalence ratio continues to increase, the lack of oxygen produces the formation of any carbon oxides, and the carbon dioxide mole fraction approaches zero.

Conclusion

When plotting stoichiometric and equilibrium temperature, equilibrium temperature is generally lower than what is predicted from stoichiometry. The temperature depression is due mainly to the dissociation of carbon dioxide into carbon monoxide in equilibrium. Increasing bond order has a larger effect on the temperature than the number of carbon atoms in saturated hydrocarbons, causing ethylene and acetylene to have a larger gap

between their stoichiometric and equilibrium temperatures. Additionally, acetylene produces, by far, the highest temperature, which explains its use in welding.

The competition for oxygen governs the behavior of very rich combustion. As conditions become very rich, the formation of carbon lowers the equilibrium temperature. At low temperatures, equilibrium shifts to favor carbon dioxide over carbon monoxide.

Methane, ethane, propane, butane, and ethylene are fairly stable gases. Their dissociation results in a small number of products. Acetylene is a very energetic, unstable gas which, in equilibrium, exothermically and explosively decomposes. It is dissociated into *many* different products. Indeed, acetylene gas bottles are specially constructed to limit the explosion hazard.

The plots made for the different gases under extreme conditions help illustrate the activity in the reactions. By visualizing the dissociation of different gases, conservation of energy is shown, and the difference between stoichiometry and equilibrium can be explained.

Bibliography

Lyons, John W. Fire. New York: Scientific American Books, Inc., 1985.

Sonntag, Richard E. and Gordon J. Van Wylen. Fundamentals of Classical Thermodynamics. New York: John Wiley and Sons, Inc., 1973.

Spaulding, D. Brian. Combustion and Mass Transfer. Pergamon Press, 1979.

Coats, Douglas E. TEP for Windows: A Combustion Analysis Tool. Nevada: Software and Engineering Associates, Inc., 1993.

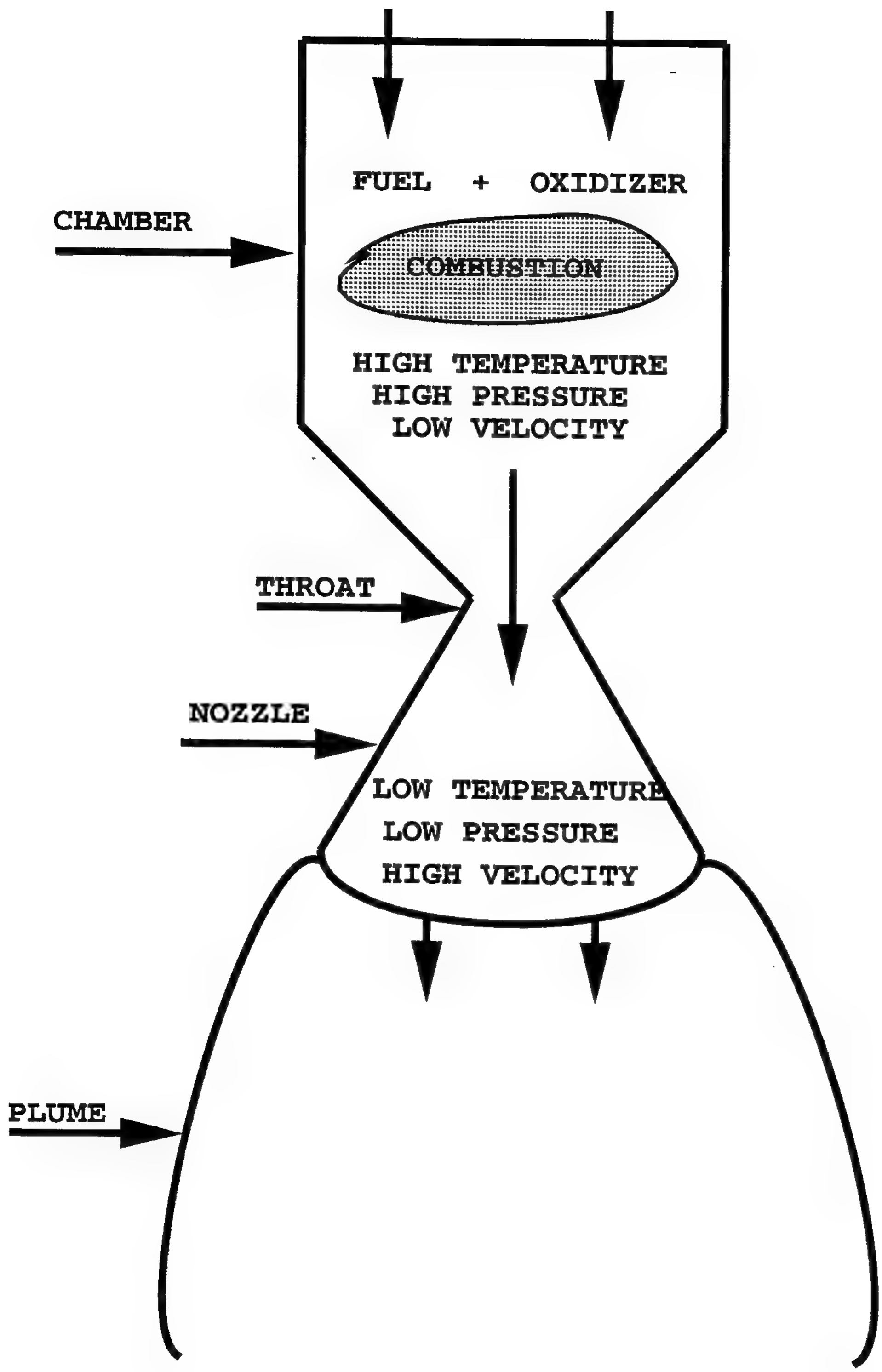

FUEL + OXIDIZER
CHAMBER
COMBUSTION
HIGH TEMPERATURE
HIGH PRESSURE
LOW VELOCITY
THROAT
NOZZLE
LOW TEMPERATURE
LOW PRESSURE
HIGH VELOCITY
PLUME

Figure 1

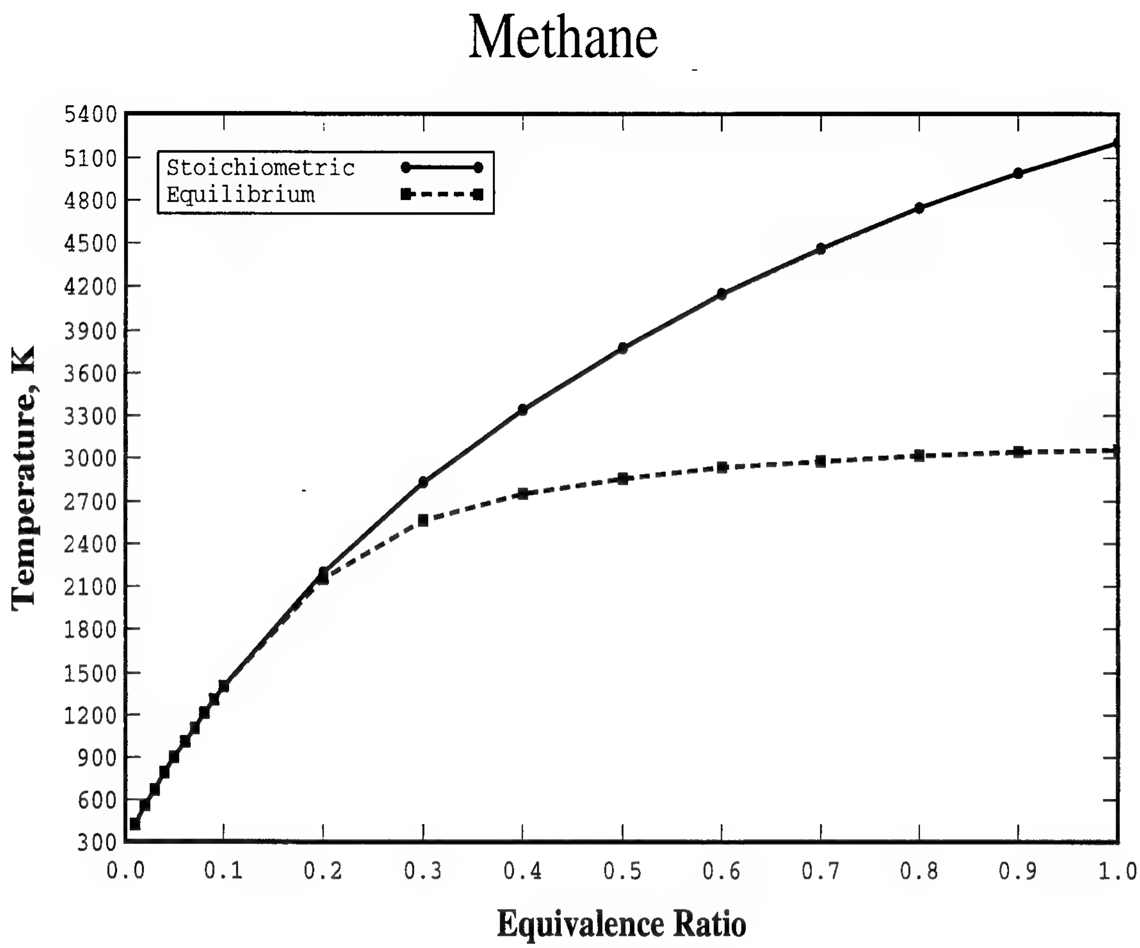

Methane
Stoichiometric
Equilibrium
Temperature, K
Equivalence Ratio
5400
5100
4800
4500
4200
3900
3600
3300
3000
2700
2400
2100
1800
1500
1200
900
600
300
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0

Figure 2

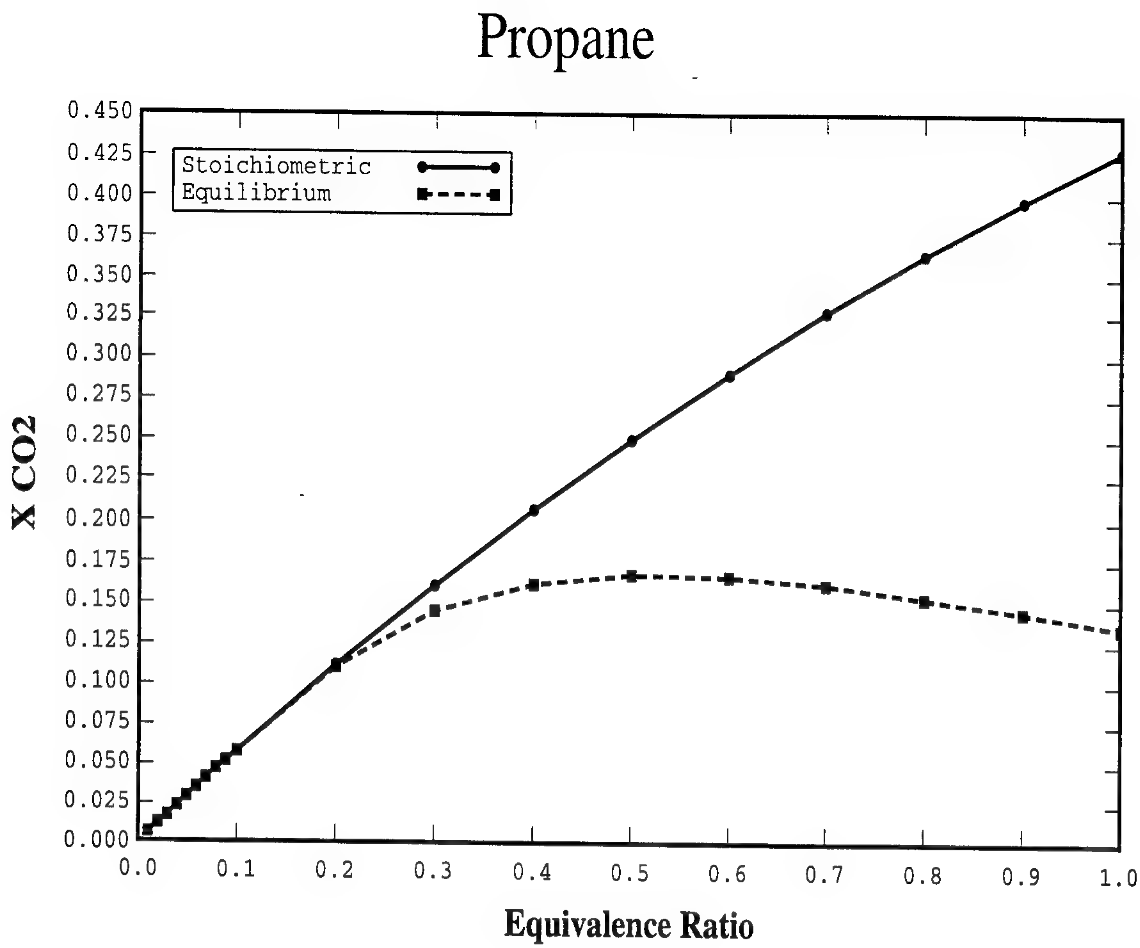

Propane
Stoichiometric
Equilibrium
X CO2
0.450
0.425
0.400
0.375
0.350
0.325
0.300
0.275
0.250
0.225
0.200
0.175
0.150
0.125
0.100
0.075
0.050
0.025
0.000
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Equivalence Ratio

Figure 3

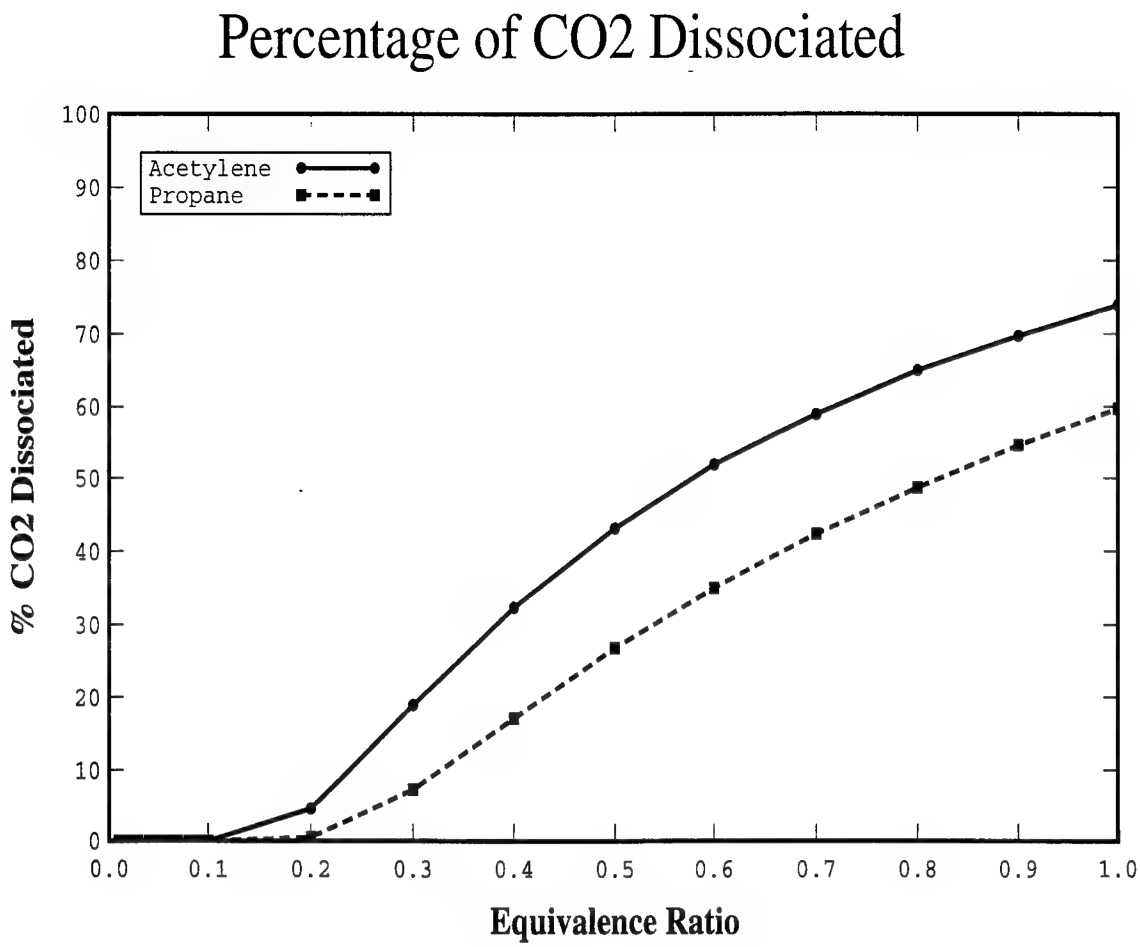

Percentage of CO2 Dissociated
100
90
80
70
60
50
40
30
20
10
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Acetylene
Propane
% CO2 Dissociated
Equivalence Ratio

Figure 4

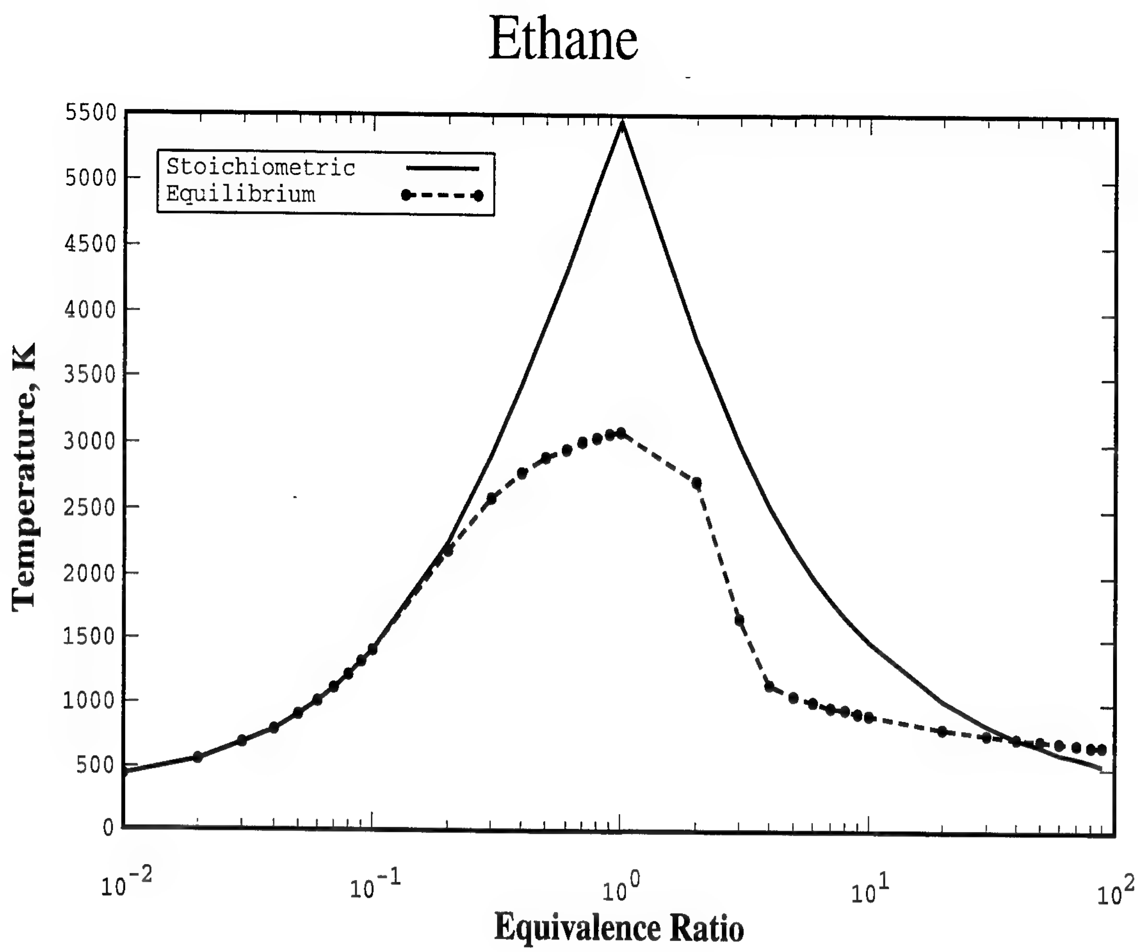

Ethane
Stoichiometric
Equilibrium
Temperature, K
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
Equivalence Ratio

Figure 5

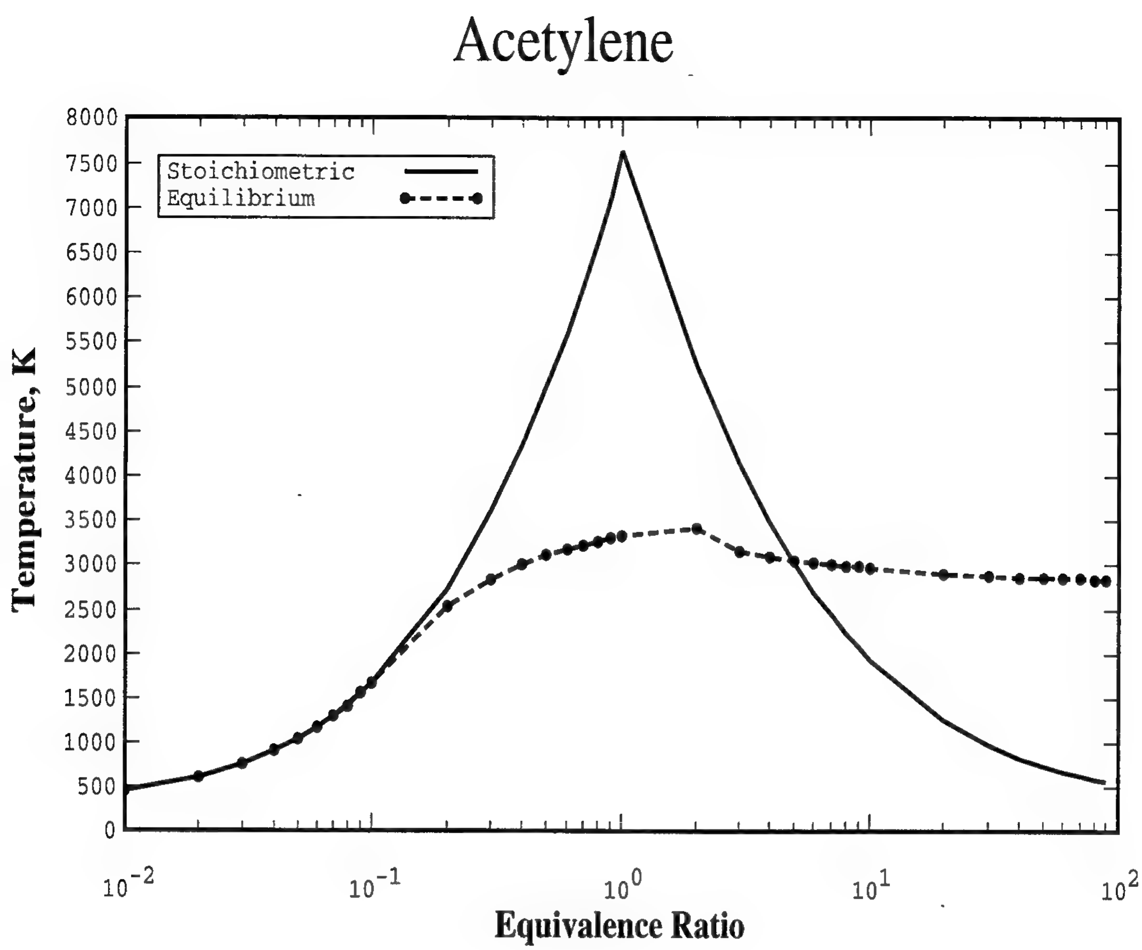

Acetylene
Stoichiometric
Equilibrium
Temperature, K
Equivalence Ratio
8000
7500
7000
6500
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}

Figure 6

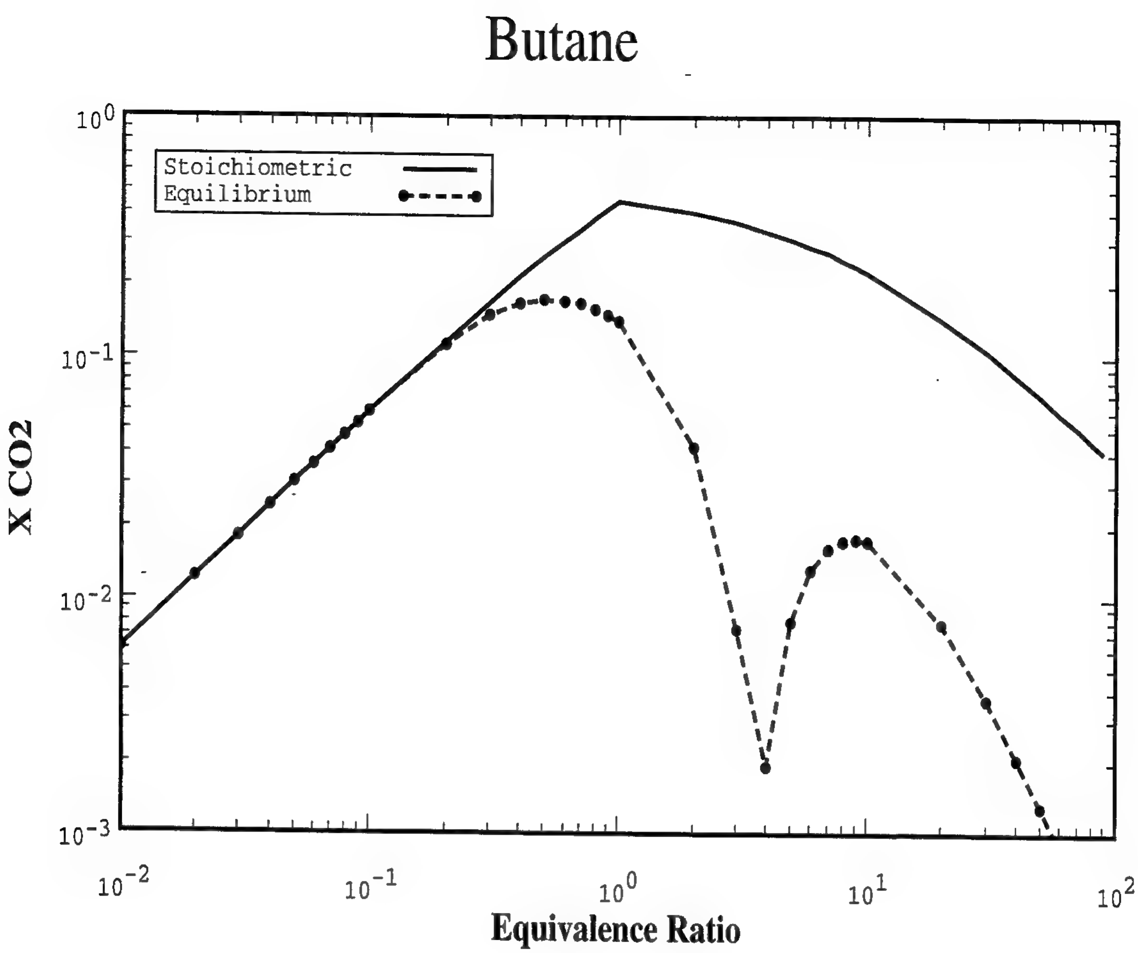
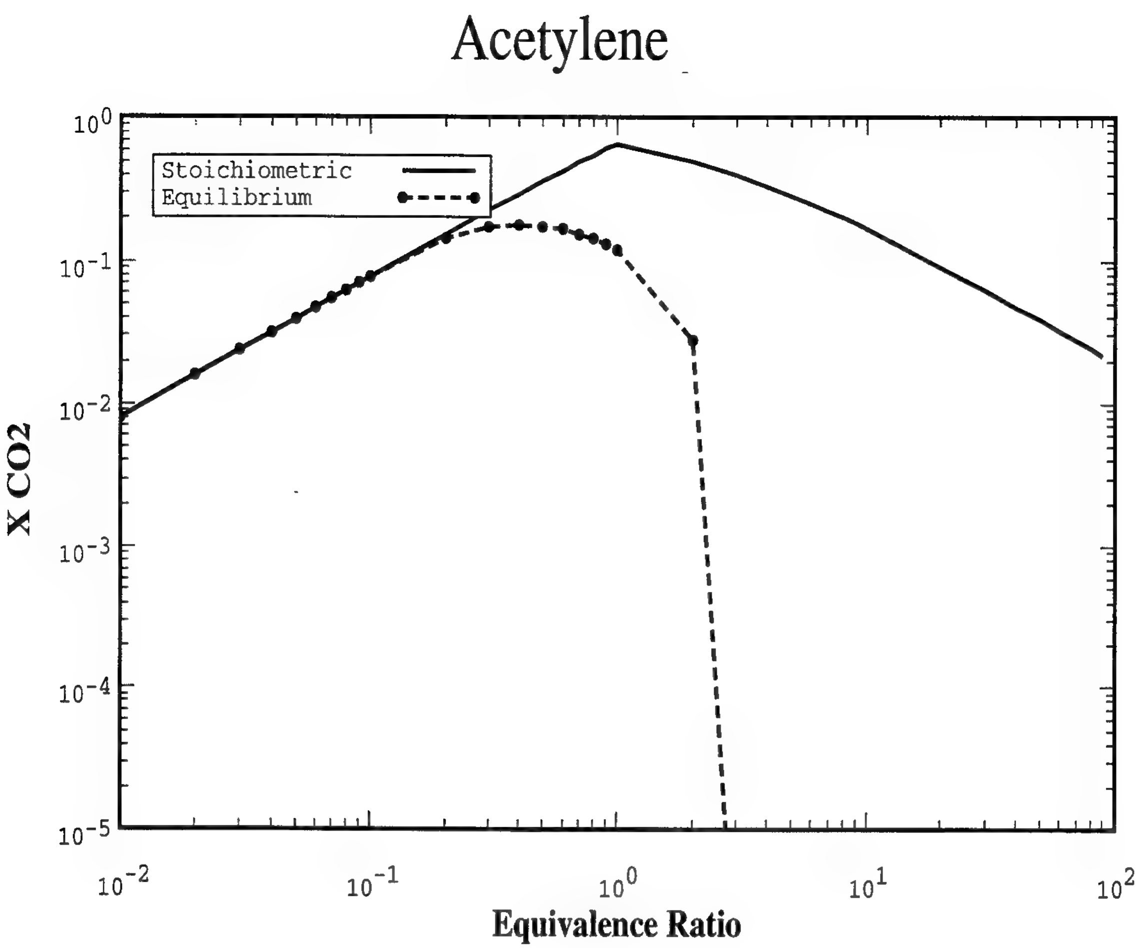
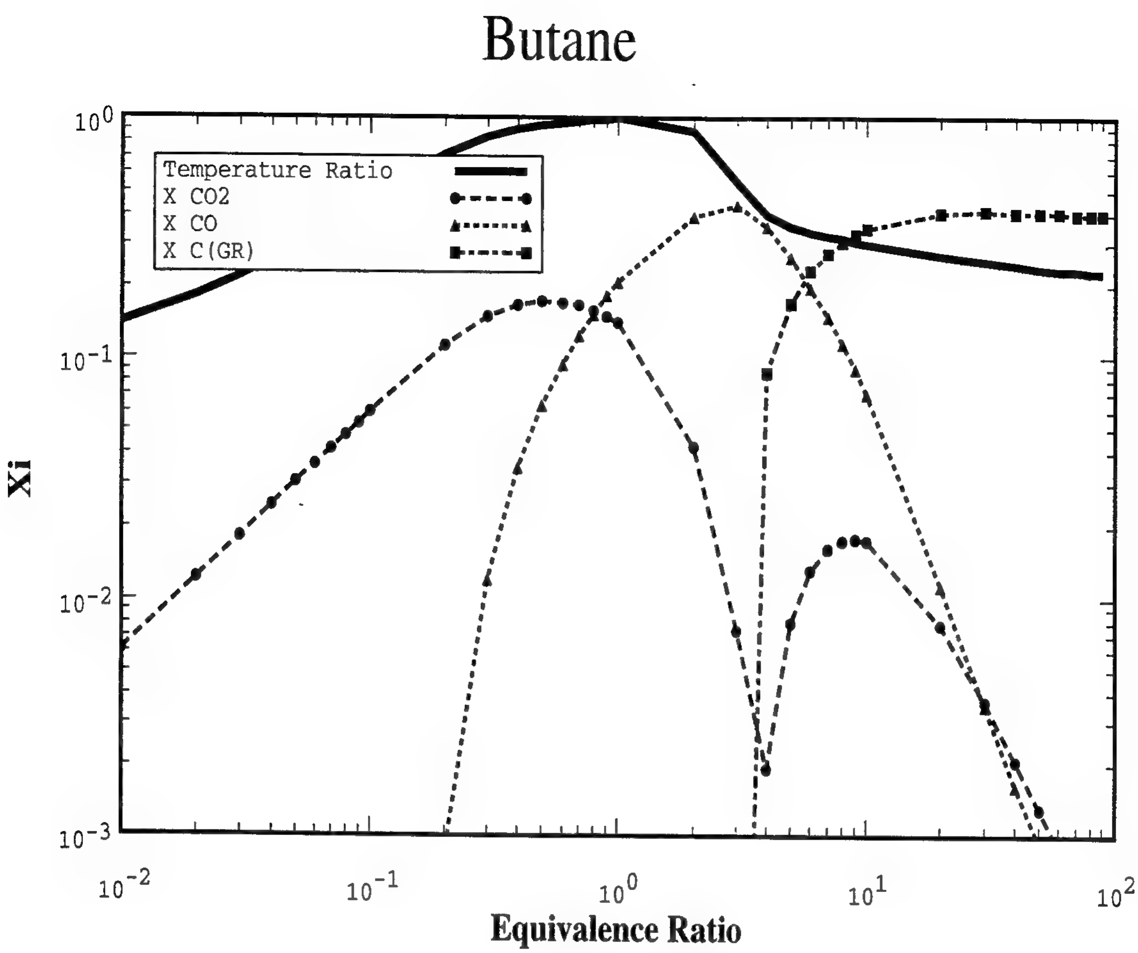

Butane
Stoichiometric
Equilibrium
X CO2
10^0
10^-1
10^-2
10^-3
10^-2
10^-1
10^0
10^1
10^2
Equivalence Ratio

Figure 7



Acetylene
Stoichiometric
Equilibrium
X CO2
Equivalence Ratio
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}

Figure 8



Butane
Temperature Ratio
X CO2
X CO
X C(GR)
10^0
10^{-1}
10^{-2}
10^{-3}
Xi
10^{-2}
10^{-1}
10^0
10^1
10^2
Equivalence Ratio

Figure 9

FUEL	DISSOCIATION TEMPERATURE	DECOMPOSITION PRODUCTS, MOLE FRACTION CH4	H2	C(GR)	C2H	H	C2H2
METHANE	297 K	0.99995	0.00003	0.00002	0.00000	0.00000	0.00000
ETHANE	604 K	0.65951	0.07239	0.26810	0.00000	0.00000	0.00000
PROPANE	629 K	0.56369	0.08826	0.34804	0.00000	0.00000	0.00000
BUTANE	637 K	0.52241	0.09119	0.38640	0.00000	0.00000	0.00000
ETHYLENE	1006 K	0.03973	0.46027	0.50000	0.00000	0.00000	0.00000
ACETYLENE	2825 K	0.00002	0.30941	0.64640	0.00194	0.02938	0.01277

Table 1 Adiabatic Dissociation of Hydrocarbons at Constant Pressure
* Initial Fuel Temperature is 300K

AN ANALYTIC CAPABILITY FOR PREDICTING STABILITY OF LIQUID SUPPLY SYSTEMS

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Final Report for:
High School Apprenticeship Program
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Sponsored by:
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and

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Arnold Air Force Base, TN

August 1994

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An analytical simulation for predicting stability in liquid supply systems was demonstrated through application to the cryogenic liquid rocket engine propellant supply system proposed for test cell J-4 at AEDC. The simulation is a collection of separate codes capable of predicting low, intermediate, and high frequency instability. Low frequency instabilities, also known as chugging, originate due to coupling between the feed system and the liquid rocket engine. This study was focused toward simulating low frequency stability of the propellant supply system. Overall system admittance, pressure transfer function, and stability were calculated for a range of propellant supply system and liquid rocket engine (LRE) operating conditions. The proposed propellant supply system and liquid rocket engine used for this study were based on existing design drawings and the RL10-3-3A, respectively. Results from the simulation indicate that the liquid oxygen and liquid hydrogen propellant supply systems are unconditionally stable.

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An analytical simulation for predicting stability in liquid supply systems was demonstrated through application to the cryogenic liquid rocket engine propellant supply system proposed for test cell J-4 at AEDC. The simulation is a collection of separate codes capable of predicting low, intermediate, and high frequency instability. Low frequency instabilities, also known as chugging, originate due to coupling between the feed system and the liquid rocket engine. This study was focused toward simulating low frequency stability of the propellant supply system. Overall system admittance, pressure transfer function, and stability were calculated for a range of propellant supply system and liquid rocket engine (LRE) operating conditions. The proposed propellant supply system and liquid rocket engine used for this study were based on existing design drawings and the RL10-3-3A, respectively. Results from the simulation indicate that both the liquid oxygen and liquid hydrogen propellant supply systems are unconditionally stable.

Nomenclature

LOX - Liquid Oxygen

LH_2 - Liquid Hydrogen

G(s) - Admittance

$m'_i(s)$ - Mass flow perturbations

$\Delta p'(s)$ - Pressure perturbations

p(x,s) - Pressure as a function of x and frequency

$p_g(s)$ - pressure response function looking toward engine

Introduction

Combustion stability is defined in terms of pressure fluctuations. Stable operation is a prerequisite for LRE combustors because high-frequency combustion instabilities carry the potential for serious damage and catastrophic engine failure. Low-frequency instabilities can interfere with vehicle operation or damage instrumentation. Several classes of instabilities have been identified in LREs. (Ref. 1). These have historically been classified by their frequency range: low, intermediate, and high.

Low-frequency, or chug, is typically less than several hundred hertz. The wavelength is much larger than

characteristic dimensions of either the chamber or the feed system. However, there may be wave motion in the propellant feed lines. This instability usually begins with a low amplitude and grows linearly. A very low frequency instability is caused by propellant flow rate oscillations that result from pump amplification of the fluctuations of the pump inlet pressure. Chug instabilities can be eliminated by increasing the pressure drop in the injector, increasing fluid entrance, and decreasing chamber volume.

Intermediate-frequency instabilities, or buzz, are not particularly damaging if they remain at low amplitude, but may degrade performance, total impulse or thrust vector. In some cases the amplitude increases to the point of triggering a high frequency mode. There is usually wave motion in the propellant feed system. Although there may be wave motion in the chamber, the phase and frequency does not usually correspond to an acoustic mode. Buzz is often encountered in development programs on engines that are designed to throttle over a wide thrust range.

High-frequency instability, also known as resonant combustion, or acoustic instability, is the most destructive type of instability. The propellant supply system is often excluded in the study of high-frequency instabilities. The sustaining energy for these instabilities is derived from the combustion of fuel in the combustion chamber (Ref. 2). It is only modestly dependent on the propellant supply system.

Stability is a critical issue in the development of LREs as well as any turbine engine combustor or stationary power unit combustor. In addition, the distributed propellant supply system required to support ground testing can provoke system instabilities, and therefore, its dynamic performance must be assessed during the design. To support these efforts, analytical codes were identified and acquired from NASA Marshall Space Flight Center. These codes were made operational on AEDC computer systems and demonstrated with application to the proposed J-4 propellant supply system.

Problem Statement

Demonstrate an analytical simulation capability for predicting stability in the proposed J-4 cryogenic liquid propellant supply system. An inherent outcome of this study will be an understanding of supply system dynamics, code applicability, and the sensitivity of code results to supply system geometry and liquid rocket engine operation.

Approach

Analytical codes were acquired from NASA Marshall Space Flight Center to assess stability. The package of codes consisted of 4 separate codes (Refs. 4-7) capable of independent execution The codes were made operational on a personal

computer with a 386 processor. Code operation was verified through application to check cases. In addition, this process enabled code input requirements to be defined and code output to be evaluated and understood. Typical instability modes in liquid rocket engines and their associated propellant supply systems were identified through literature review.

Two of the four codes, ADMIT and NYQUIST, were applied to predicting the stability of the planned J-4 cryogenic propellant supply system. Current plans call for test cell J-4 (Ref. 3, Fig. 1) to be converted to support liquid rocket engine testing. Test capabilities are required for planned upgrades to the RL10 (Fig. 2) in support of the ATLAS launch vehicle.

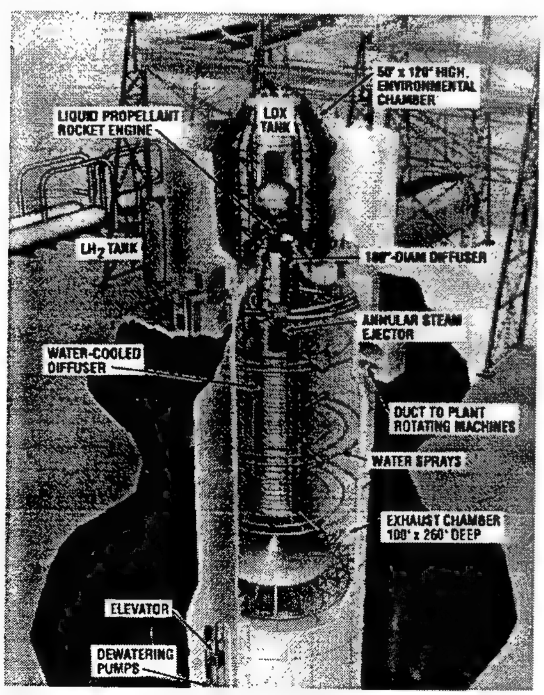

Figure 1 . Cut-away View of the J-4 Test

Theoretical Foundation of the NASA Codes

Several approaches have been documented in the literature for mathematically describing the propellant feed system response. The approach used

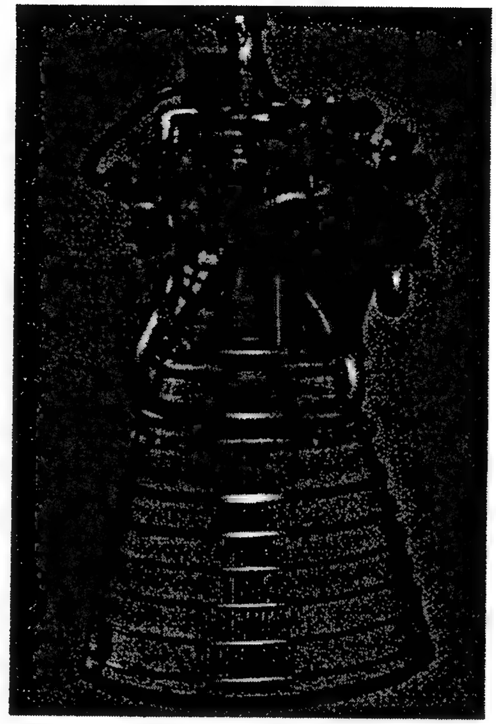

Figure 2. RL10A-3-3A Rocket Engine.

in the NASA codes is based on derivation of a transfer function from the set of equations for the components by writing each variable as the sum of a steady-state value and a perturbation (Ref. 1).

$$G(s) = \frac{m_i'(s)}{\Delta p'(s)}$$

Therefore, large fluctuations in pressure most likely produce small values of

admittance. Values of admittance are calculated for specified values of frequency for a given geometrical system at specified operating conditions of mass flow. Computed values of the impedance vary with physical configuration of the system component: straight pipe, elbow, valve, orifice, pump. These frequency domain techniques have an advantage over time domain techniques in that classical stability criteria can be used. However, time domain analyses do provide a technique for incorporating nonlinearities.

The pressure transfer function is defined at any point x as follows:

$$\frac{p(x,s)}{p_g(s)}$$

where p_g is the pressure response function looking toward the engine. This plot is indicative of the pressure variation as a function of frequency in the supply system

Overall stability at low frequencies can be assessed using a Nyquist plot or a phase gain plot (i.e., Bode). The Nyquist stability method is based on the theorem of Cauchy which states that if a function F(s) is analytic inside a given domain, D, except for a finite number of poles (singularity), then when s traces the contour in a clockwise direction, the vector representing F(s) in a complex plane will rotate about the origin and the number of complete clockwise rotations that F(s) makes is equal to the difference between the number of zeros and the number of pose of F(s) (Fig. 3). In other words, the number of rotations of the vector about (0,0) in the imaginary, real plane represents the number of non-unconditionally stable solutions. An alternative procedure is to plot f(s) = F(s) -1. Therefore, the rotation of the stability vector is monitored about -1 + I.

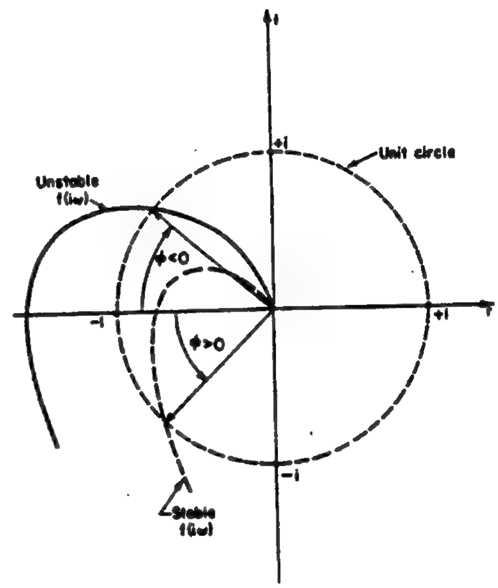

Figure 3. Simplified Nyquist Plot.

The gain and phase plots provide an alternate approach to assessing stability, although no new information is provided beyond that of the Nyquist plot. A computed gain of less than one indicates that the perturbations cannot be magnified. That is, the system is stable. A computed gain greater than one indicates that perturbations may grow if induced. Therefore, the system is not unconditionally stable.

Because the SSFREQ and HIFREQ codes were not used in this study, the theory was not investigated.

Code Description

The NASA codes consist of four separate programs (Refs. 4-7): ADMIT, NYQUIST, SSFREQ, and HIFREQ. The codes operate on a personal computer. A description of each program follows.

ADMIT: Admit calculates the impedance (inverse of admittance) looking toward the tank and the impedance looking toward the engine in the calculation of the pressure transfer function. This program yields three graphs: a piping diagram plotted on the same graph as the admittance, a 3-D surface plot of the pressure transfer function, and a contour plot of the pressure transfer function.

NYQUIST: The Nyquist Code can use the admittance for the LOX lines only or the FUEL lines only. This program plots the Nyquist curves for four cases: either LOX lines only, FUEL lines only, both LOX lines and FUEL lines, or neither LOX nor FUEL lines. This program also yields three different types of graphs: the piping layouts for either or both lines present, the Nyquist curves in the complex plane, and the Phase-gain plots of the Nyquist equation.

SSFREQ: The SsFreq (steady-state) Code works in the intermediate frequency range where the piping, engine, and nozzle all interact. The program computes n (pressure interaction index) for the given range of frequencies and τ's (sensitive time lags). After these computations are complete the user may request a plot of n vs. τ for that frequency. After the frequency ranges have been run, all of the n vs. τ are plotted on the same graph.

HIFREQ: The HiFreq Code is used to determine the instabilities occurring at a higher range of frequencies. The program handles three different modes of oscillations; radial, transverse, and longitudinal. The three main running options for the codes are: 1. a given combustion response is input and the resulting complex frequency is calculated, 2. interaction index (N) and time lag (TAU) are input and the resulting complex frequency is calculated, and 3. for a given frequency the combustion response and N, TAU are determined (this option is used to generate N, TAU stability maps).

Code Application

The code was applied to the proposed LOX/LH2 cryogenic propellant supply system planned for the J-4 test cell at AEDC. The J-4 Test Cell is a vertically oriented test complex designed for the static testing of large liquid and solid propellant engines and entire propulsion systems at simulated altitudes of approximately 100,000 ft.

The proposed cryogenic propellant supply system (Fig. 4) includes. two

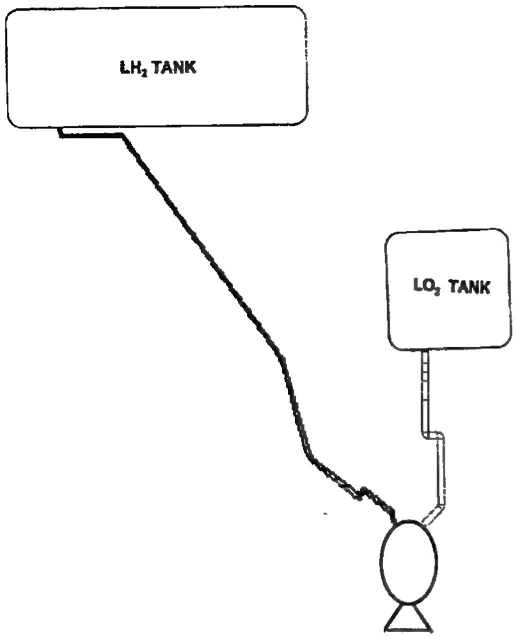

Figure 4. Schematic of the J-4 Propellant Supply System.

separate supply lines: one liquid oxygen line and one liquid hydrogen line. The LOX line is approximately 25 feet long with 6 inch inside diameter vacuum jacketed pipe. The LOX supply tank holds 4000 gallons. The LH2 line is approximately 100 feet long with 6 inch inside diameter vacuum jacketed pipe. The LH2 supply tank holds 10000 gallons.

Table 1. Supply System Baseline Configuration		
	LOX	LH2
Tank Volume (ft^3)	534.7	1336.7
Mass Flow (lbm/sec)	28.25	5.65
Density (lbm/ft^3)	71.4	4.54
Bulk Modulus (lbm/ft^2)	11858830	11858830
Manifold Volume (ft^3)	13.5	4.5
Manifold Bulk Modulus (lbm/ft^2)	11833460	11833460

Results

Baseline propellant supply system and engine operating conditions were established (Tables 1, 2). ADMIT and NYQUIST were executed for these conditions and results obtained for both the LOX and LH2 lines. The active frequency component of the LOX and LH2 systems are near 10 Hz and 24 Hz respectively. Both systems are unconditionally stable (Figs. 5 and 6).

Table 2. Engine Baseline Configuration	
Total Mass Flow (lbm/sec)	33.95
Chamber pressure (lbf/ft^2)	56664
Pressure Drop Across Orifice (lbf/ft^2)	29800
Transport Lag	0.1
Characteristic Velocity (ft/sec)	7749
Mixture Ratio	5.0
Characteristic Time Constant	0.00233
Change in Velocity with Mixture Ratio (ft/sec)	-315

A parametric study was performed (Table 3). The study indicated that code results show little sensitivity of calculated stability with volume of tank, bulk modulus, transport lag, and characteristic time constant. Results are sensitive to LOX and LH2 mass flow rates, engine chamber pressure, and pressure drop across the orifice. The propellant

Table 3. Variation of Input Values for Parametric Study					
CASE	0	1	2	3	4
O/F	5.0	4.49	5.44	5.0	5.0
LOX flow (lbm/sec)	28.25	27.27	28.89	28.25	28.25
LH2 flow (lbm/sec)	5.65	6.08	5.31	5.65	5.65
Total flow (lbm/sec)	33.90	33.35	34.20	33.90	33.90
Chamber Pressure (psia)	393.5	393.0	391.1	393.5	393.5
Characteristic Velocity (ft/sec)	7749	7867	7635	7749	7749
Pressure Drop Across Orifice (lbf/ft^2)	29800	29800	29800	35760	23840

supply system becomes unstable when the pressure drop across the orifice is decreased by 50% from the nominal operating conditions. However, this operating condition is not likely to occur.

Conclusions and Recommendations

An analytical simulation for predicting stability in liquid supply systems was demonstrated through application to the cryogenic liquid rocket engine propellant supply system proposed for test cell J-4 at AEDC. The simulation was successfully implemented using a 386 personal computer. The simulation confirmed the stability of the proposed propellant supply system. Some understanding of supply system stability was gained through a parametric study of code input variables. Additional work is required to implement and demonstrate an analytical capability for predicting intermediate and high frequency combustion stability.

References

1. Harrje, D.T., Reardon, F.H., "Liquid Propellant Rocket Combustion Instability", NASA SP-194, 1972.

2. Crocco, Luigi and Cheng, Sin , 'Theory of Combustion Instability in Liquid Propellant Rocket Motors', AGRAD, 1956.

3. 'Test Facilities Handbook', Arnold Engineering Development Center, March 1984.

4. Armstrong, Wilbur C., 'User's Manual for ADMIT: Admittance and Pressure Transfer Function Developed for Use on a PC Computer', June 1992.

5. Armstrong, Wilbur C., 'User's Manual for NYQUIST: Liquid Rocket Nyquist Plots Developed for Use on a PC Computer', June 1992.

6. Armstrong, Wilbur C., 'User's Manual for SSFREQ: Intermediate Mode Stability Curves Developed for Use on a PC Computer', June 1992.

7. Armstrong, Wilbur C., 'User's Manual for HIFREQ Interactive Version for the PC of Mitchell's FDORC Code,' June 1992.

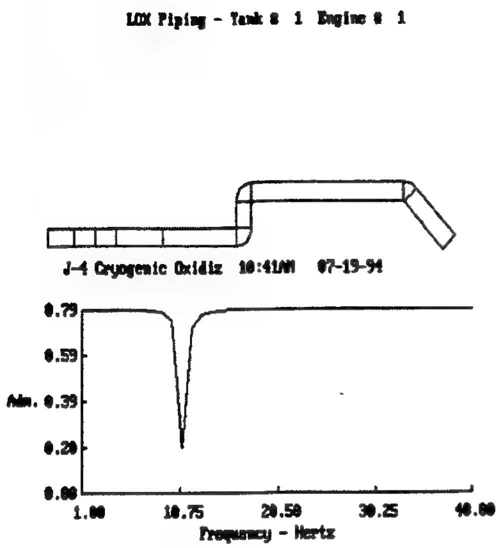

Figure 5a. Piping Diagram and Admittance Plot for the LOX Supply Line

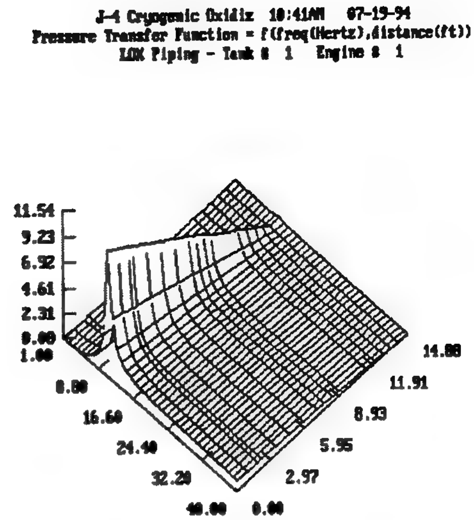

Figure 5b. . Pressure Transfer Function for the LOX Supply Line

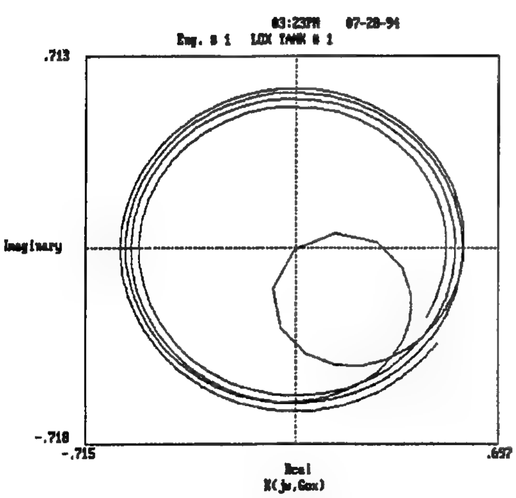

Figure 5c. Nyquist Plot for the LOX Supply Line

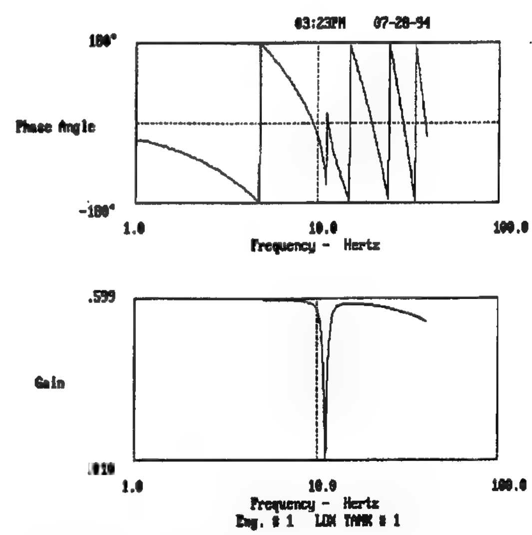

Figure 5d. . Phase-Gain Plots of the LOX Supply Line

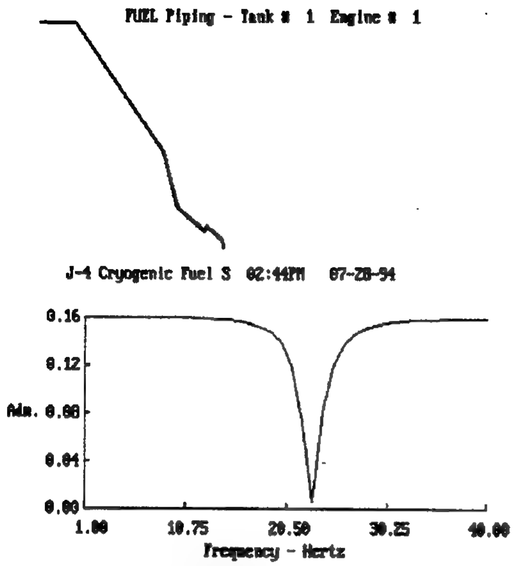

Figure 6a. . Piping Layout and Admittance Plots of the LH2 supply Line

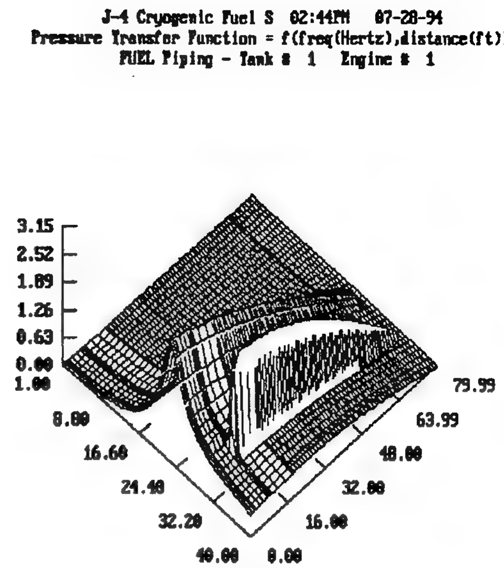

Figure 6b. Plot of the Pressure Transfer Function for the LH2 Supply Line

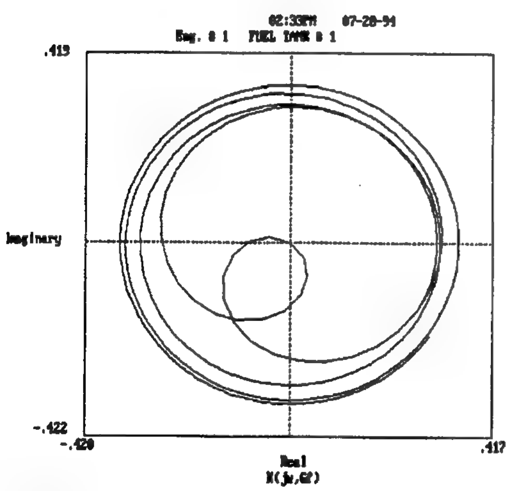

Figure 6c. NYQUIST plot for the LH2 Supply Line

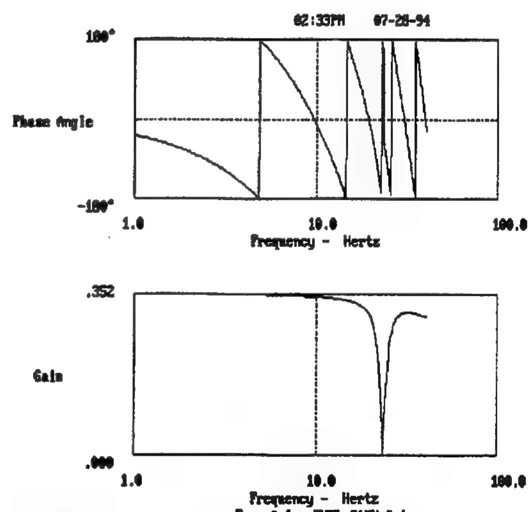

Figure 6d. Phase-Gain Plots of the LH_2 Supply Line

POWER SYSTEMS ANALYSIS

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Final Report for:
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August 1994

POWER SYSTEMS ANALYSIS

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Abstract

A power system analysis was performed on the Plenum Evacuation System. Field data and manufacturer's data were collected to support this effort and a database program was created to manage the information.

POWER SYSTEMS ANALYSIS

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Introduction

In order for any power system to work reliably, it must have an adequate system of protective devices. These devices protect systems from damage and limit power outages to the smallest possible part of the system. The objectives of the project were to assist in the analysis of the Plenum Evacuation System (PES), which is a system of synchronous motors that extract air from the Propulsion Wind Tunnel (PWT), and to design a program to manage field data.

Methodology

Before the analysis procedure on PES could begin, it was necessary to collect data on the motors, relays, breakers, and other components of the system. In order to store and manage this data, a database management program was needed. The steps involved in creating the program began with learning the dBase IV programming language. After this was accomplished, the actual coding commenced. The program had to be easy to use, able to search the data and extract certain records, and output the data to a printer. Once the basic framework of the program was designed, advanced functions such as an extensive

system of arrays to handle user input was created. Using these arrays, the program's interface was able to support a system of pop-up menus. These pop-up menus give the user a list of all choices available for a given command.

Working with the data collected from a field survey, manufacturer's instruction books, and other sources, a protective device coordination study of PES was accomplished. Two software packages, EDSA and Captor, were used to determine proper settings for the protective equipment. These programs have preprogrammed specifications for many kinds of conduit, relays, and other components found in electrical systems. They allow engineers to manipulate device settings and see their effects before the actual system is modified. As a result of the collection of data on the elements in the system and analyzing the data with EDSA and Captor, the PES system's protective device coordination was completed.

Results

The Plenum Evacuation System evaluation was completed and protective devices were set to reflect the findings of the analysis. A user friendly database program was created to aid in the collection of field data for the power systems studies team.

Thanks to:

Steven George

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Randy Dotson

Rick McCoy

Bill Simmons

Bill Mayberry

James Mitchell

and the other members of GB-13